FINANCIAL PERFORMANCE OF TIMBERLAND AND FARMLAND REITS IN THE UNITED STATES

by

SRIJANA BARAL

(Under the Direction of BIN MEI)

ABSTRACT

Over the last three decades, timberland and farmland have been well recognized as the investment vehicles that have grown from niche investments to mainstream alternative asset classes. Their increasing popularity is due to several attractive financial characteristics including high risk-adjusted returns, inflation hedging, and portfolio diversification benefits. Although several studies have examined various aspects of timberland investment, investigation of timberland real estate investment trust (REIT) performance is still fragmented. Additionally, no study has evaluated the characteristics and performance of farmland REITs. The first part of this dissertation reviews the existing literature on the development and financial performance of timberland REITs in the United States. The results show expansion in timber REIT conversions, reformation of tax policies associated with timberland REITs, and the use of more advanced asset pricing models in evaluating timberland REIT performance. The second part examines the time-varying relationships of timberland REITs with private-equity timberland, real estate, and financial assets. The results reveal that the large-cap stock and idiosyncratic factors are the major contributors of timberland REIT volatility and that the characteristics of timberland REIT change over time for 2000Q1-2019Q4. The last part compares the integration of farmland and timberland REITs with their private equity counterparties and other selected asset classes for 2013Q1-2021Q4. The results show that the contributions of large-cap stocks to farmland and timberland REIT volatility vary over time and that these two entities are still in the developing phase. Overall, this dissertation attempts to provide a better understanding on the financial performance of timberland and farmland investments in the United States.

INDEX WORDS: Alternative investment, Farmland investment, Forest finance, Real estate, State space model, Timberland investment, Volatility decomposition

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2022

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DEDICATION

To my loving and supporting husband Anil and my parents.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my major advisor, Dr. Bin Mei. Thank you for your intellectual supervision and invaluable support throughout this program. Your responsiveness, insightful feedback, and practical suggestions have helped me finish this program and grow professionally.

I would also like to thank my advisory committee members, Drs. Pete Bettinger, Jacek Siry, and Gregory Colson. I appreciate your time for serving in my research committee, providing valuable advice for coursework, and supporting throughout this process. I would like to acknowledge the Harley Langdale Center for Forest Business and the Warnell School for providing wonderful networking opportunities and other resources for personal and career advancement.

I am very thankful to Tyler Reeves and Hector Restrepo for always being available to answer my questions about coursework and research. Also, I cannot begin to express my appreciation for my friends in Athens who made this place feel like home when away from home, listened to my endless class and research stories, cheered me on, and celebrated each accomplishment.

I deeply thank my parents and sister back home for unconditional love, patience, and support. Lastly, I want to thank my best friend and husband, Anil, for your love, support, and sacrifices you have made for us to pursue this program together. Thank you for riding along on this forestry education journey for more than 12 years. None of this would have been possible without you. Thank you everyone for helping me get through this adventure.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS v

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER

1 INTRODUCTION 1

2 DEVELOPMENT AND PERFORMANCE OF TIMBER REITS IN THE UNITED STATES: A REVIEW AND SOME PROSPECTS 5

3 THE TIME-VARYING LINK OF PUBLIC TIMBER REITS WITH PRIVATE TIMBERLAND, REAL ESTATE, AND FINANCIAL ASSETS 41

4 INTEGRATION OF PUBLIC FARMLAND AND TIMBERLAND REITS WITH THEIR PRIVATE EQUITY COUNTERPARTIES AND SELECTED ASSET CLASSES 65

5 CONCLUSIONS 93

REFERENCES 96

LIST OF TABLES

Page

Table 2.1: Publicly traded timber real estate investment trusts (REITs) in the US 29

Table 2.2: Tree species distribution in different timberland regions of timber real estate investment trusts (REITs) 30

Table 2.3: List of reviewed journals that published articles related to real estate investment trusts… 31

Table 2.4: Summary of methodologies employed in the financial analysis of timber REITs 32

Table 3.1: Descriptive statistics of selected return indices (2000Q1-2019Q4) …………………57

Table 3.2: Regression estimates of the factor sensitivities of timber REIT returns on other asset returns 58

Table 3.3: Volatility decomposition of timber REIT return 59

Table 4.1: Public farmland and timberland real estate investment trusts (REITs) in the US 82

Table 4.2: Summary statistics and correlations of selected return indices (2013Q1-2021Q4) 83

Table 4.3: Return sensitivity of farmland and timberland REITs to pure factors..........................84

Table 4.4: Contributions (in percentage) of pure factors to farmland and timberland REIT return volatility 85

LIST OF FIGURES

Page

Figure 2.1: Area of timberlands in thousands of hectares (shades of green) managed by current timber real estate investment trusts (REITs) in different states of the US.........................34

Figure 3.1: Quarterly returns of selected return indices (2000Q1-2019Q4).................................60

Figure 3.2: Time-varying volatility contributions of S&P500, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index (uNTI), NCREIF Transaction based Property Index (NTBI), AAA long-term corporate bonds (LTC), and idiosyncratic factors to timber REIT return..61

Figure 4.1: Trend of selected return indices (2013Q1-2021Q4)..86

Figure 4.2: Time-dependent volatility contributions of orthogonalized S&P 500, small-cap stocks, long-term corporate bonds, private real estate, private farmland, and idiosyncratic factors to farmland REIT return...87

Figure 4.3: Time-dependent volatility contributions of orthogonalized S&P 500, small-cap stocks, long-term corporate bonds, private real estate, private timberland, and idiosyncratic factors to timberland REIT return..88

CHAPTER 1

INTRODUCTION

Timberland Investment in the United States

Timberland investment involves growing and managing forest for the purpose of producing financial return by selling timber or other forest-related products. Timberland ownership in the United States (US) has undergone significant changes in the last couple of decades, changing hands from vertically integrated forest products companies to timberland investment management organizations (TIMOs) and the securitized forms of ownerships such as Master Limited Partnerships (MLPs), letter stocks, and real estate investment trusts (REITs). However, the MLP and letter stock structures did not exist for a long time (Caulfield and Flick 2000). In contrast, TIMOs and timberland REITs emerged as the new avenues of investing in timberland and attracted growing interest of individual and institutional investors due to their distinct investment opportunities, market structure, and performance. For example, Plum Creek, once the largest MLP, converted itself to a public timberland REIT in 1999.

Today, the industrial timberlands in the US are predominantly held by TIMOs and timberland REITs. TIMOs do not own timberland but provide timberland investment and management services to investors. Timberland REITs are publicly traded timber companies that own and manage timberland. These two entities have grown in number and size over the years. As of 2020, there were more than 30 TIMOs and 4 timberland REITs in the US (Mei and Clutter

2020). The business structure of TIMO and timberland REITs differs from each other and should be considered during timberland investment decision making.

Farmland Investment in the United States

The US farmland is recognized as one of the important real estate sectors with roughly $2.7 trillion in the total asset value (Statista 2022). Farmland investment has witnessed boom-and-bust cycles mostly in the late 1900s due to the fluctuations in the commodity prices and reformations in the fiscal and monetary policies. In the early 1970s, low interest rates, high commodity prices, and the higher expectations of exporting more products involved "bidding wars" among investors. As a consequence, the farmland prices skyrocketed. However, in the early 1980s, the farmland market collapsed causing the "farm crisis" (Stewart 1994). Thus, institutional investors tended to refrain farmland investment for some time. A few years later, investors started farmland investment for portfolio diversification and inflation hedging. In 1995, the National Council of Real Estate Investment Fiduciaries Farmland Index was introduced that allowed investors to assess farmland performance. Then, in the 21st century, the institutional farmland investment continued to grow rapidly due to the increasing demand for food coupled with the growing purchasing power of the population. In 2013, the first farmland REIT emerged in the US (Lekovic et al. 2018).

There are three established ways to invest in farmland. They are direct land purchase, purchasing shares of publicly traded farmland REITs, and investing through crowdfunding platforms focused on farmland. Direct purchase of farmland is the most common and traditional way of investment that involves several options. For example: investors can buy an existing farm through a sale-leaseback transaction[1] or buy an existing farm and lease to a new farmer. Purchasing

[1] In sale-leaseback transaction, current farmer will manage the land and pay rent to the new investors.

shares of farmland REITs are the most accessible and low-cost way to invest in farmland. Lastly, investment via crowd funding flatforms (e.g., AcreTrader, Harvest Returns) is done using internet, which are primarily available to the accredited investors only (DiLallo 2022).

Motivations of the Dissertation

Timberland REITs in the US are growing in size and gaining popularity among institutional investors, especially for large-scale timberland investments. Since the establishment of the first timberland REIT in 1999, several studies have evaluated the financial performance of timberland REITs using various empirical approaches. However, a systematic review of those literature is still lacking. Chapter 2 aims to fill this research gap by consolidating the relevant timberland REIT literature within the following topics: (1) development of REITs; (2) tax as a factor of REIT growth and its implications; (3) financial performance; and (4) methods used for the financial analyses of timberland REITs.

Timberland, in general, has been widely accepted as an alternative investment vehicle with high risk-adjusted returns that provides exposure to the real estate investment. However, the roles of timberland REITs in mixed-asset portfolios consisting of stocks, bonds, and other asset classes continue to be debated (La and Mei 2015; Piao et al. 2016). Chapter 3 provides a clearer picture on this by examining the time-varying risk and return relationships between timberland REITs and other asset classes including private-equity timberland, commercial real estate, and financial assets.

Farmland is a relatively new alternative asset class that offers various investment opportunities and has witnessed substantial development and growth in the recent years, specifically with the establishment of publicly traded farmland REITs. However, there is a lack of information regarding the characteristics of farmland REITs and their performance in multi-asset portfolios. Chapter 4 aims to address this by evaluating the integration of farmland REITs with private-equity farmland and other selected asset classes. Further, the performance of farmland REITs is compared with that of timberland REITs.

Objectives of the Dissertation

The main goal of this dissertation is to examine the risk and return characteristics of farmland and timberland investments. The specific objectives are: (i) to summarize the evolution of REITs and synthesize peer-reviewed literature evaluating the financial performance of timberland REITs, (ii) to examine the time-varying relationships of timberland REITs with private-equity timberland, commercial real estate, and financial assets, (iii) to evaluate and compare the time-dependent risk and return characteristics of farmland REITs with those of timberland REITs.

Chapters 2-4 achieve these three specific objectives. I present them as three independent journal articles that are formatted according to the structure of the journals. i.e., each article has its own sections of introduction, literature review, data, methodology, results, and discussion and conclusions including the references. Lastly, chapter 5 summarizes the main conclusions for this dissertation and posits some future research prospects.

CHAPTER 2

Development and performance of timber REITs in the United States: A review and some prospects[2]

[2] Baral, S. and B. Mei. 2022. Published by *Canadian Journal of Forest Research*, 06/14/2021. Reprinted here with permission of the publisher, 03/22/2022.

Abstract:

Timber real estate investment trusts (REITs) are companies that own and manage timberland and generate revenue by harvesting and selling timber or other forest-related products. Due to their popularity with investors, timber REITs in the United States attracted growing research interest in the recent decades. This necessitates a review of existing knowledge on timber REITs' evolution and their financial performance over the years. In this review, we summarized the history and development of timber REITs, discussed tax policies applicable to timber REIT growth and their implications. We also reviewed past studies focusing on the financial performance of timber REITs and synthesized methodologies used in those studies. At the end, we posited the possibility of consolidation waves in the timber industry and identified some opportunities for future research. This review can shed some new light on the evolution of public timber REITs and their financial performance.

1. Introduction

Forestland in the United States comprises about 310 million ha, representing 34 percent of the total land area in the country. Out of which, about 208 million ha are considered commercial timberlands with an estimated market value of $460 billion (Newell and Eves 2009, Oswalt et al. 2019). The US South, in particular, holds 41% of the US timberlands and produces roughly 60% of total timber in the country (Brandeis and Hodges 2015; Prestemon et al. 2015). Regarding timberland ownership in the US, about 145 million ha are privately owned and roughly 63 million ha are public (Oswalt et al. 2019). These timberlands provide a myriad of ecosystem services to the American people in terms of clean water, outdoor recreation and many more. Therefore, the forest sector makes a significant contribution to the overall economy of the US.

Timberland investment is the acquisition and management of timberland for the production and sale of timber or other forest-related products. There are three common ways to invest in timberland, (i) direct purchase and management; (ii) investment funds via intermediaries, such as timberland investment management organizations (TIMOs), that manage timberland for investors; and (iii) owning stocks of publicly traded timber firms (Mendell et al. 2007). These vary in terms of participation in timberland management, liquidity, and control. Direct investment involves active timberland management and offers high control but low liquidity, whereas timber REIT investment does not involve active participation and offers very limited control but high liquidity (Fu 2017). The third option to invest in timberland is accessible to investors of all levels because it often requires lower initial investment than the first two. Since the 1980s, timberland ownership has shifted from vertically integrated forest products companies to TIMOs and timber real estate investment trusts (REITs). These two entities gradually gained popularity especially in large-scale transactions in timberland investments and increased competitiveness in the forestland market (Mei 2019, Kuusela and Lintunen 2019).

REITs are companies that own or finance income-producing real estate properties. The US Congress authorized the organizational form of REIT in 1960, which allowed all the investors to invest in real estate properties. To maintain a REIT status, companies should satisfy asset, income source, dividend distribution, and ownership and management structure requirements imposed by the federal tax law. Major criteria of the Internal Revenue Code in the Sections 856 - 860 are: (i) at least 75% of all assets and gross income must be in real estate; and less than 25% of assets in taxable REIT subsidiaries, (ii) at least 90% of taxable income must be distributed to REIT shareholders as dividends, (iii) must have at least 100 shareholders for one-year-old REIT, and (iv) REITs must be taxable as a domestic corporation. For tax purposes, REITs can deduct all distributed dividends from their taxable income so as to eliminate federal income taxes, and shareholders must pay taxes on dividends and capital gains at ordinary income tax rates and capital gain tax rates, respectively (Corgel et al. 1995; Congressional Research Service 2016).

Since 1970, REITs have been growing rapidly due to high demand from investors. The number of REITs in the US increased from 34 in 1971 to more than 225 in 2020 with a corresponding market capitalization of $1.5 billion to more than $1 trillion (Sun 2013a; NAREIT 2020). Currently, the US REIT market has become the most established in the world. The National Association of Real Estate Investment Trusts categorizes REITs into three broad classes (equity, mortgage, and hybrid REITs) and 12 property sectors (office, industrial, retail, lodging, residential, timberland, health care, self-storage, infrastructure, data center, diversified, and specialty REITs). Out of these property sectors, this review focuses on publicly traded timberland REITs, or timber REITs in short. Currently, there are four timber REITs in the US, which are Rayonier, PotlatchDeltic, Weyerhaeuser, and CatchMark (Table 2.1). Altogether, these timber REITs manage over 6 million ha of timberlands in 20 states across several regions of the US (Figure 2.1). Pine plantations in the Southeast, conifer plantations in the Pacific Northwest, and mixed hardwood stands in the Northeast are the main concentrations of timber REIT holdings (Table 2.2). As of 2014, timber REITs managed about 4.2% of total timberlands in the US and this has been increasing on a yearly basis (Hood et al. 2015). Today, the combined market capitalization of timber REITs surpasses $30 billion or about 6% of the total market capitalization of publicly traded REITs in the US (Stevenson 2013; NAREIT 2020).

In the finance and forestry disciplines, there has been literature synthesis of REITs, timberland investments, and timberland transaction costs. Corgel et al. (1995) reviewed literature on REIT investment decisions, financing decisions, and risk return issues. They found varying REIT performance due to different sample periods and performance measurement approaches. Mei (2019) synthesized timberland investment literature within the following themes: 1) Investment vehicles and return indices; 2) Role of timberland in a portfolio; 3) Asset pricing of timberland; 4) Public timber REITs; and 5) Decision-making under uncertainty, especially with the emerging woody bioenergy market. Hiegel et al. (2020) discussed the importance of understanding timberland transaction costs and due diligence for effective evaluation of their impacts on timberland values, timber supply, and sustainable timber management. Chudy and Cubbage (2020) provided a review of timberland as an alternative asset class and found that expected returns, portfolio diversification, inflation hedging, and liquidity and risks were the key factors affecting forestry investments. Overall, these review articles have advanced our knowledge on the general aspects of REITs and timberland investments. Timber REITs are increasing in size and popularity, however, a thorough literature review of empirical analyses on timber REITs is still lacking.

Hence, our goal is to fill this knowledge gap by summarizing the relevant literature on timber REITs published since 1999, the year when the first timber REIT was established in the US. This study could provide valuable insights into the financial performance of timber REITs and identify some research trends. The rest of this article is organized as follows: section 2 provides the methods of literature search; section 3 explains the development of timber REITs along with a short profile of each timber REIT; section 4 discusses tax implications for timber REITs; section 5 reviews the financial performance of timber REITs; section 6 summarizes empirical methods used in the past studies; and the last section concludes the article.

2. Methods

To identify existing literature on timber REITs, we performed a systematic online database query followed by a comprehensive bibliography section search of each literature. We focused the literature search on English-written articles on timber REIT evolution, tax policies, financial performance, asset pricing, and risk evaluation. First, we searched peer-reviewed articles in major online databases such as Google Scholar and Web of Science with key words “timber REIT”, “timberland investment”, and “public timberland asset”. In this round, we selected articles based on title, abstract, and keywords. Second, we searched the bibliography sections of selected articles from the first round to collect more publications on timber REITs. For this, we examined the title of each publication in the bibliography section and checked the content in the text where they have been cited. After a careful assessment of 117 collected articles, we reviewed 42 articles related to timber REIT analysis. The majority of the reviewed articles were from *Forest Policy and Economics, Journal of Forestry*, *Forest Science*, *Journal of Forest Economics*, *Journal of Real Estate Portfolio Management*, *Canadian Journal of Forest Research*, *Forest Products Journal,* *and Journal of Real Estate Research* (Table 2.3). We accessed all the articles through the University of Georgia library. Additionally, we visited the individual timber REIT websites and collected their 10-K reports to gather more historical information about their businesses. We calculated the market capitalization of each timber REIT as total shares outstanding times price per share as of 31 December 2019, with all data obtained from Wharton Research Database Services (WRDS 2020).

3. Development of timber REITs in the US

Timber REITs are specialized REITs that own and manage timberland and generate significant revenue by harvesting and selling timber or other forest-related products. Qualification of timberland as a REIT was possible because of the 1997 Real Estate Investment Trust Simplification Act, which repealed the 30% gross income tax rule (Caulfield and Flick 2000). Until the early 20th century, forest products companies owned most of the industrial timberlands in the US. However, such companies sold their timberlands or converted themselves into REITs over the past few decades. As a consequence, by 2006, roughly 80% of the industrial timberlands were classified as a TIMO/REIT (Smith et al. 2009). In terms of timber growing regions, the US South witnessed the most significant changes in timberland ownership (Clutter et al. 2005).

Timber REIT conversions gained popularity for several reasons. First, unlike the traditional C-Corporation structure, timber REIT income is taxed only once at the shareholder level. At the corporate level, REITs can deduct dividends from their taxable income and thus do not owe corporate tax. This makes timber REIT a relatively tax-efficient alternative of timberland investment. Second, timberland assets are recognized by their book values or historical transaction prices according to the US generally accepted accounting principles, which are often much less than their fair market values, especially under vertically integrated forest products companies. However, timber REITs alleviate this undervaluation problem by incorporating more frequent and recent transaction information into the current pricing of their timberlands (Piao et al. 2017). Another reason for REIT conversion is liquidity and transparency of timber REITs. Financial information of timber REITs is routinely disclosed to the general public via registration statements, periodic reports, and other forms filed to the US Securities and Exchange Commission.

Plum Creek was the first timber REIT in the US, converted from a Master Limited Partnership in 1999. Realizing several advantages of REITs over other forms of securitized ownerships, more forest products firms completed conversions over the years, e.g., Rayonier in 2004, Potlatch and LongView Fibre in 2006, Weyerhaeuser in 2010, and CatchMark in 2014 (Hunt 2012; Mendell 2016). LongView Fibre remained as a timber REIT only between January 2006 and April 2007. Currently, there are four timber REITs in the US: Rayonier, PotlatchDeltic, Weyerhaeuser, and CatchMark.

Rayonier started business as the Rayonier Pulp and Paper Company in Washington in 1926. Before becoming ITT Rayonier in 1968, a subsidiary of ITT Corp, the company invested in the southeast timberland and established a couple of pulp mills. Rayonier was spun off from ITT Corp and began to trade on the New York Stock Exchange in 1994. Later in 2004, Rayonier completed REIT conversion and operated its core businesses in forest resources, real estates, and performance fibers. In 2014, the performance fibers business was spun off from Rayonier to become an independent public company as Rayonier Advanced Materials. In 2020, Rayonier acquired Pope Resources for $656 million. With $3.7 billion in total assets, Rayonier generated a total revenue of $859 million and a net income of $37 million as of 2020 (Rayonier 2020).

Potlatch was founded in 1903. During the great depression in the mid-1950s, the company merged with other timber and lumber companies into Potlatch Forests, Inc. to overcome their financial challenges and to increase their pulp and paperboard production. Potlatch Forests, Inc. merged with more paper companies and plywood mills and converted into the Potlatch Corporation in 1973. In 2006, Potlatch completed REIT conversion and focused its activities on timberlands, wood products, and real estate businesses. Pulp-based businesses were spun off into an independent company from Potlatch in 2008. Potlatch acquired more timberlands in 2015 and merged with Deltic Timber in 2018, thus changing its name to PotlatchDeltic Corporation. With $2.3 billion in total assets, PotlatchDeltic generated a total revenue of $1 billion and a net income of $166 million as of 2020 (PotlatchDeltic 2020).

Weyerhaeuser began timberland business in 1900 in Washington. It established several mills for pulp, board, plywood, wood-fiber, and bark processing between 1945 and 1949. Additionally, the company purchased large timberland in the US South in 1956 and again in 1969. Public trading began on the New York Stock Exchange in 1963. The company expanded its real estate business by acquiring more real estate in 2006, all of which, however, were sold in 2014. To become a more competitive timberland owner and operator, Weyerhaeuser completed timber REIT conversion in 2010. In 2013, it acquired 261,022 ha of timberland from Longview Timber and in 2016, it merged with Plum Creek. With $16.3 billion in total assets, Weyerhaeuser generated a total revenue of $7.5 billion and a net income of $797 million as of 2020. Weyerhaeuser is the largest timber REIT in the US that operates more than 38 wood products manufacturing (Weyerhaeuser 2020).

CatchMark, formerly a TIMO named as Wells Timberland, has been owning and managing timberland since 2007. It purchased around 12,140 ha of timberlands in 2012 and went public on New York Stock Exchange the following year. With $0.6 billion in total assets, CatchMark generated a total revenue of $104 million and a net income of -$17 million as of 2020 (CatchMark 2020).

4. Tax as a factor of timber REIT growth and its implications

After REIT establishment by the Cigar Excise Tax Extension Act of 1960, reformation of several tax laws reinforced REIT growth over time. First, the 1976 Tax Reform Act allowed REITs to hold properties for sale and to avoid taxes on income generated from that sale. Then, the 1986 Tax Reform Act repealed the 5/50 rule for REIT's first taxable year, allowed capturing of paid fees, and removed tax advantages of other real estate investment vehicles, thus making REIT conversion easier. All these changes contributed smooth development and operation of REIT as an active investment (Hunt 2012). The Omnibus Budget Reconciliation Act of 1993 relaxed REIT shareholder ownership constraints by modifying the 5/50 rule for pension funds, which increased attractiveness of REITs to pension funds (Friday et al. 1999). In addition, the 1997 Real Estate Investment Trust Simplification Act eliminated three tax provisions affecting REITs: (i) rule associated with disqualification of REIT rental income for tax purposes; (ii) tax on retained capital gains; and (iii) rule on 30% gross income from the asset sale. Later in 1999, the REIT Modernization Act allowed REITs to own taxable subsidiaries that would not previously qualify as a rental income (Chan et al. 2003). All such new tax legislations that were also associated with timberland firms were viewed as drivers of timberland ownership change from forest products companies to timber REITs.

Since REITs started owning timberlands, more tax laws related to timber REITs were passed or proposed. In 2003, the Jobs and Growth Tax Relief Reconciliation Act reduced maximum capital gain tax from 20% to 15% for timber sold between 2003 through 2009. Prior to reducing safe harbor timberland transaction holding time to 2 years by the Timber Revitalization and Economic Enhancement Act of 2008, the American Jobs Creation Act of 2004 modified the safe harbor rule for timber REIT. This rule made disposals of underlying assets (timber sale) an unforbidden transaction, as received by REITs in general (National Timber Tax 2020). The 2008 act relaxed three other timber REIT provisions on timber transactions: (i) considered timber gain as a real property sales and as a qualified income under section 631(b) and section 631(a) respectively if timber harvest was within taxable REIT subsidiary, (ii) counted mineral loyalty income as a "good" income for the REIT income test purpose for those properties previously associated with timber production, and (iii) increased securities of taxable REIT subsidiaries from 20% to 25% of a REIT's asset value (Mendell and Sydor 2008). These provisions further increased attractiveness of timber REIT investments among institutional investors and eased conversion of forest products companies into timber REITs.

Additionally, several tax proposals affecting timber REITs had been introduced in the Congress. For example, Representative David Camp released the 2014 Tax Reform Act draft proposal to exclude timber as a real estate for REIT taxation purpose or to treat REIT as a corporation where the double taxation rule applies. Other similar proposals that were released in the Congress did not come to fruition, but they could possibly serve as a baseline for future tax reform bills. While the financial effects of tax reform acts or proposals have been analyzed in the past for private timber REITs and family forest owners (Cushing 2006; Cushing and Newman 2018; Baral et al. 2020), studies evaluating their impacts on public timber REITs are scarce. Sedjo and Sohngen (2015) used timber supply model to analyze the effects of the 2014 proposed federal tax laws on costs and net returns of public timber REITs and found negative impacts on investors. At the top individual tax rates of 39.6% and 35%, respectively, costs increased by 31% at 35%

maximum corporate tax rate and by 24% at 25% maximum tax rate. Additionally, removal of favorable capital gain tax provision and elimination of REIT as a legal business form of timberland ownership increased tax on harvested timber by 20%.

The 2017 Tax Cuts and Jobs Act reformed several federal income tax laws applicable to timber sector. The act retained treatment of timberland as a real property and introduced a new rule on REIT dividend deduction that allows 20% of "qualified business income" deduction, thus reducing shareholders' taxes on REIT dividends (Internal Revenue Service 2020). Looking forward, more changes on timber REIT tax rules may take place.

5. Financial performance of timber REITs

REIT conversions and inclusion of timber REITs in a portfolio have attracted many researchers to study financial performance and investment decisions of timber REITs. Additionally, the wealth of return data has provided unique opportunities to infer underlying characteristics of timber REITs through financial modeling. With the shift in timberland ownership, Mendell et al. (2008) and Piao et al. (2017) evaluated the short- and long-term market reactions to timber REIT conversions respectively. Mendell et al. (2008) evaluated four timber REITs (Plum Creek, Rayonier, Potlatch, and LongView Fibre) conversion announcements between 1999 and 2006, and found a significant short-term abnormal returns indicating investor's preference of holding industrial timberland within REITs in the short run. Piao et al. (2017) excluded LongView Fibre and included Weyerhaeuser in their study and employed four approaches and three benchmarks to compute abnormal returns. Their results corroborated those of Mendell et al. (2008), showing significant long-term abnormal returns. Therefore, the structural changes in the timber sector have added values to timber firms in both the short and long runs.

Sun et al. (2013) categorized changes in industrial timberland ownership into four groups, which included seven timber REIT conversion announcements and four land acquisitions by timber REITs and assessed their impacts on the financial performance of forest firms. Again, the positive abnormal returns were significant for timber REIT conversion announcements. However, land acquisitions by timber REITs generated weak and negative abnormal returns. Moreover, the asset volatility increased for all groups except for the land acquisition by timber REITs. Observation of timber REIT conversions through the lenses of sustainable forestry has generated concerns in regard to environmental impacts induced by new forest management regime. Fernholz et al. (2007) pointed out that conservation easements and forest certification were some of the tools to address such issues for resource protection, risk reduction, and asset enhancement.

Using the parametric and non-parametric approaches, Mei and Clutter (2010) assessed the financial performance of public equity timberland investments consisting of timber REITs and other types of public timber firms. Public equity timberland performed similar to the market and was unable to diversify risk. The authors suspected that the REIT conversions by Plum Creek, Rayonier, and Potlatch caused overall decreasing trend in systematic risk. Moreover, they reported a minimal impact of gloomy market on the systematic risk during the subprime residential mortgage blowup. Results from another study by Wan et al. (2013) corroborated the results in Mei and Clutter (2010).

The great recession of 2007-2009 is regarded as the most significant economic downturn in the US history. The collapse of the US housing market led to contraction of liquidity in financial markets and generated financial turmoil. Such events unavoidably affected timber REITs in the country. Sun (2013a) evaluated time-varying risk of timber REITs for 2007-2009 recession period. They selected a combination of generalized autoregressive conditional heteroscedasticity

(GARCH) model and extreme value theory after assessing four alternative risk measurement approaches. Results showed 99% of absolute daily value-at-risk between 5.03% and 8.32%, and daily losses up to 13% of timber REIT investments due to market volatility. Using similar approaches, Sun (2013c) examined the relation between price variation and trading volumes of three timber REITs. The GARCH model showed a positive correlation between conditional volatility of asset returns and abnormal trading volumes. This implied that the same underlying information flow influenced returns and volumes of timber REITs. The bivariate extreme value models revealed a positive relation between absolute values of return and trading volumes. During extreme market movements, the return-volume relation of timber REITs was not very strong and stable. Regarding return-volume relation in the tail, the positive association was stronger during the market stress (lower tail) than that during the market boom (upper tail) for some timber REITs, thereby signifying somewhat symmetric relationship. In the equity market, assessment of price-volume relation of public firms is primarily useful to understand financial market structure, mechanism of information flow, and market price volatility measured by trading volume (Karpoff 1987; Chen et al. 2001).

In general, REITs are recognized as an investment vehicle with portfolio diversification abilities (Wechsler 2013). Regarding the diversification benefits of timberland assets, several studies found low correlations between the timberland investments and the stock market (Sun and Zhang 2001; Cascio and Clutter 2008). La and Mei (2015) investigated portfolio diversification through timber REITs and found no general trends within timber REITs or between timber REITs and S&P500. This indicated a long-run diversification potential of timber REITs when each REIT was considered as a unique candidate. However, other short-term studies showed fewer diversification benefits of timber REITs (Sun 2013b; Wan et al. 2013; Piao et al. 2016). With the increasing interest of investors on timber REITs for portfolio diversification, it is important to understand correlations between the stock market and the timber REITs. Understanding the basic issues associated with the theory of informational efficiency is also crucial in the financial market. Informational efficiency is the degree to which the market price incorporates all available information into an asset's value, thus facilitating better informed investment decisions. La and Mei (2013) evaluated informational efficiency of timber REITs from 1999 to 2012 and found that the timber REITs were less efficient than other forest products companies and the S&P 500 index, implying some potential arbitrage opportunities for sophisticated investors.

Although a number of studies in the real estate domain investigated REITs of various property types, not many studies have compared performance differences between them or their immediate counterparts. For example, Benefield et al. (2009) and Ro and Ziobrowski (2011) compared diversified and specialized REITs and reported better performance of diversified equity REITs based on the overall market conditions during the given sample period. Such comparative studies remain an interesting topic for REITs of other property types. In forest finance, a number of studies investigated and compared various aspects of timber REITs with private timberland markets, other forms of securitized ownership, other REITs, and lumber future prices (Mei and Clutter 2010, 2020; Sun 2013c; Piao et al. 2016; Clements et al. 2017).

In contrast to private-equity timberland, public equity timberland could not outperform the market and had higher systematic risk (Mei and Clutter 2010). This suggested limited potential of timber REITs in improving the efficient frontier. Scholtens and Spierdijk (2010) also showed no improvement in mean variance frontier when public timberland assets were included in the portfolio. Along the same line, Sun (2013b) confirmed that the timber REIT structure introduced unavoidable systematic risk into timberland investments and provided limited diversification benefits than private-equity timberland. Under the mean conditional value-at-risk framework, Restrepo et al. (2020) revealed time varying role of timberland in a mixed-asset portfolio and more diversification benefits of private-equity timberland. Regarding the inflation hedging, Wan et al. (2013) found strong and consistent hedging ability of private-equity timberland, and improvement in hedging ability of forest products companies only after the REIT conversions. However, Yao et al. (2014) reported higher mean excess returns of timber REITs than their private-equity counterparts that barely earned expected returns. They also underscored easy trading, liquidity, and transparency of public timber REITs over the private-equity timberlands.

Unlike Master Limited Partnerships, timber REITs do not have a fixed investment time period and provide more investment opportunities to institutional investors. When evaluating return-volume relationships of timber REITs versus Master Limited Partnerships, Sun (2013c) found larger total standing shares, daily trading volumes, and average daily turnover rates of timber REITs. However, most of the timber REITs had weaker return-volume relation than Master Limited Partnerships under the extreme market movements. Regarding the volatility of returns, trading volumes explained only a small portion of conditional volatility of timber REIT returns. Another study compared performance differences between timber REITs, other specialized REITs, and common REITs (Piao et al. 2016). Unlike other REITs, timber REITs had the lowest unconditional variance, largest market capitalizations, no excess returns, and were least sensitive to recessionary shocks. Although timber REITs are a part of specialized REITs, they had the highest conditional volatility as opposed to other specialized REITs. Additionally, timber REITs were more vulnerable to idiosyncratic shocks and had limited portfolio diversification ability. In comparison to forest products firms, timber REITs exhibited better performance due to tax efficiency and better liquidity (Mendell et al. 2008). Yao and Mei (2015) assessed risk–return relationship between 16 forestry-related assets and innovations in state variables to consider risks of unfavorable shifts in the investment opportunity set. While the public-equity timberland assets, consisting of timber REITs, earned significant positive excess returns over 1988-1999, forest products and timber products earned insignificant excess returns in the whole sample period of 1988–2011.

Return indices of private- and public-equity timberland investments differ greatly with respect to financial leverage, liquidity, business segments, transactions, and geographic allocations. Considering these differences, Mei (2015b) constructed a pure-play timberland index that had pure exposure to timberland business segment of timber REITs and found that the pure-play index differed significantly from private timberland indices and that the public timber market tended to lead the private market. Recognizing the above-mentioned differences between private- and public-equity timberland markets, Mei and Clutter (2020) examined returns and short-run information transition of REITs and TIMOs with full adjustments on the composition of these asset returns. Results showed higher systematic risk of timber REITs than TIMOs and only TIMOs as a risk diversifier in portfolio optimization. REIT returns helped to predict TIMO returns and both assets exhibited positive abnormal returns. The outputs clearly showed the importance of understanding differences in return indices of the same underlying asset for better investment decisions.

Regarding the linkage between lumber prices and timberland investments, Clements et al. (2017) evaluated connectivity between lumber futures and timber REITs and found a positive relation of lumber prices and an inverse relation of capitalization rates with public timber REITs in the long run. In the short run, changes in timber REIT prices were consistent with those in the long run. Clements et al. (2011) found a similar relationship between lumber prices and private timberland values. However, lumber futures prices had a positive relationship with timber REITs, whereas unanticipated shocks in lumber prices had a negative impact on private timberland values (Clements et al. 2011; Clements et al. 2017). Lumber and timber prices are often correlated as lumber is derived from timber. It is a principal income producing component of timber REITs because prices of timber REITs are intrinsically connected to the value of timber grown and harvested. In general, strong lumber markets indicate strong markets for sawtimber, and vice versa. That being said, timberland investors should pay attention to lumber market conditions as well. Additionally, the strength of relationship between lumber and sawtimber prices may vary by region. Therefore, implications of lumber market conditions for timberland investment decisions should be evaluated on a regional basis.

6. Methods used for financial analyses of timber REITs

In this section, we discuss some common techniques used in the financial analyses of timber REITs in the US (Table 2.4). Capital asset pricing model (CAPM), a single-factor model introduced by Sharpe (1964) that has been widely used in the finance literature, has many applications in the timberland sector. For example, Mei and Clutter (2010) used the CAPM to assess returns of private and public timberland assets. They also estimated the CAPM in the state space framework with Kalman filter to examine time-varying risk-adjusted excess return and systematic risk. Wan et al. (2013) used the CAPM under inflation and tested the hedging ability of private and public timberland assets. Mei (2017) used the CAPM and other asset pricing models in evaluating return indices of public and private timberland assets. Piao et al. (2017) constructed cumulative abnormal returns of timber REITs based on CAPM. Considering potential presence of stale pricing, Mei and Clutter (2020) used the CAPM with lagged market premium to evaluate return indices of TIMOs and REITs.

Given that the CAPM uses market risk as a single factor and does not consider many other risk factors in the economy that may affect asset pricing, several studies extended the past research by using multifactor asset pricing models. Fama-French three-factor model also includes size and value risk factors given the fact that small-size and value stocks outperform large-size and growth stocks (Fama and French 1993). This model has been applied to a variety of timberland issues, including asset pricing (Mei and Clutter 2010), inflation hedging ability (Wan et al. 2013), return indices (Mei 2017), and estimation of long-term abnormal returns (Piao et al. 2017). Another multifactor asset pricing model used in evaluating timber REITs is the arbitrage pricing theory. Yao et al. (2014) used this model to estimate the expected returns of private and public timberland investments and found that it better explained timberland returns than the CAPM. They also revealed the ability of CAPM to price public-equity but not private-equity timberland assets. However, it is a much more complicated technique and requires a careful choice of factors.

A few studies have applied other multi-factor asset pricing models to timberland. Yao and Mei (2015) used the intertemporal CAPM to assess risk-return relationships of forestry-related assets and found that the model explained 80% of the variations in the cross-sectional returns of most assets compared to the respective 5% and 37% of the variations explained by the CAPM and the Fama-French three-factor model. Piao et al. (2016) used the same approach to evaluate and compare risk-return characteristics of timber REITs, other specialized REITs, and common REITs. Results from these studies indicated higher capability of intertemporal CAPM in explaining cross-sectional returns of timber REITs and other forestry-related assets. While timberland returns are often evaluated with several parametric approaches, Mei and Clutter (2010) and Mei (2017) introduced the nonparametric stochastic discount factor approach in pricing timberland assets and identified the importance of intertemporal consumption decisions in pricing timberland.

Other techniques, such as mean-variance approach, copula modeling, and co-integration analysis have been used in detecting the short- and long-run correlations between timber REITs and the financial markets. Scholtens and Spierdijk (2010) applied the mean-variance framework to assess the diversification potential of timber REITs. Sun (2013b) estimated both constant and time-varying symmetrized Joe-Clayton copulas to assess association between the timber REITs and the equity market. La and Mei (2015) used the co-integration analysis, a time series technique that examines long-run relationship of different variables by identifying a common stochastic trend (Arshanapalli and Nelson 2008), to investigate diversification ability of timber REITs. Among these techniques of assessing relationship between timberland assets and market, the notion of copulas is a better approach as it overcomes limitations of correlations (Pfeifer 2013).

Several past studies have compared financial performance of private and public timberland investments under the framework of the modern portfolio theory, but have ignored the independent and identical distribution assumption that is critical to the distinction between single- and multi-period investment decisions (Newell and Eves 2009; Sun and Zhang 2001; Mei and Clutter 2010). Mei (2015a) addressed this issue by using the BDS test and bootstrapping method and found that returns on liquid public-equity timberland assets were independent and identically distributed whereas returns on private-equity timberland assets were not. They also pointed out that the direct comparisons of returns on private and public timberland assets can be misleading. Mei (2015b) constructed a pure-play timberland index based on public timber firms and revealed that the new benchmark tended to lead the national council of real estate investment fiduciaries timberland index. Mei (2017) compared different index construction methods of timberland investment returns, which included various national council of real estate investment fiduciaries timberland indices, transaction-based index, and a pure-play index, and offered some insightful guidance to better benchmark timber investment returns. Mei and Clutter (2020) tested information transition dynamics between TIMOs and REITs under a vector autoregression framework.

Event study is another widely used empirical analysis to assess the financial impact of a specific event. A short-term analysis tests the quickness of a market event whereas a long-term analysis tests the lasting effect. Mendell et al. (2008) and Piao et al. (2017) used this approach to examine the short- and long-term abnormal returns of timber REIT conversions, respectively. Unlike the traditional analysis, which assumes constant variance and no serial correlation, Sun et al. (2013) assessed the event-induced abnormal returns with GARCH effects by considering a cluster of volatility over time in the financial data.

Regarding the measurement of volatility in timberland investments, GARCH models (Engle 1982) are often used. Sun et al. (2013) combined the event analysis with a GARCH model to estimate time-varying conditional volatility of timber REIT returns and compared abnormal returns obtained from this model to those without GARCH effects. Sun (2013a) combined GARCH and extreme value theory to measure market risk of individual timber REITs during the tranquil and volatile market conditions. They also used parameters estimated from this approach to compute value-at-risk for both the short and long investment positions. Sun (2013c) used the same approaches to examine price variation and volume dynamics of timber Master Limited Partnerships and REITs.

Piao et al. (2016) used multivariate exponential GARCH model, which captures the leverage effect, to compare risk and return characteristics of three types of REITs. Yao and Mei (2015) also used a GARCH model to estimate innovations in state variables in pricing forestry-related assets.

Clements et al. (2017) used the vector error correction and GARCH models to investigate a connectivity between lumber futures and timber REIT prices. Restrepo et al. (2020) tested non-normal distribution of timberland returns and compared standard deviation with conditional value-at-risk as the risk metric in portfolio optimization. They concluded that standard deviation tended to underestimate the risk and conditional value-at-risk was a better risk measure.

7. Discussion and Conclusions

In this review, we summarized the development and performance of timber REITs in the US and provided some prospects for future research. Results revealed a great expansion in timber REIT conversions, mergers, and acquisitions in the last two decades. Several factors affected the growth of timber REITs in the US such as high liquidity, small amount of capital to be invested, no active management of timberland, and some tax benefits. Timber REIT success can also be linked with the housing market as 50% to 75% of timber REIT revenue comes from wood supply for homebuilding purposes (Lerner 2015). The early literature on timber REITs provided only a general description of their business activities and the advantages and disadvantages of investing in this new securitized timberland asset. As timber REITs continued to become a popular alternative investment strategy for investors, the focus of timber REIT research revolved around the impacts of REIT conversions, risk and return characteristics of timber REITs, and their financial performances over other types of real estate.

Although tax policies associated with timberlands have undergone frequent changes in the past, not many studies have evaluated its effects on timber REIT returns. As tax is considered as one of the major drivers of timber REIT conversions, changes in tax laws and its associated effects should be closely monitored and investigated. Timber REIT conversions have received a positive market reaction and introduced non-diversifiable systematic risk into timberland investments. There is some evidence that timber REITs have diversification benefits in the long run but offer no excess returns (La and Mei 2015; Piao et al. 2016). Timber REITs also provide greater liquidity than private-equity timberlands and are more tax efficient than C-Corporations. Nonetheless, several other financial characteristics of timber REITs and private timberland need to be considered while making the investment decisions.

In recent years, increasing interest of institutional investors in timberland investment has generated a need for advanced and improved analysis of this asset class. As a result, researchers applied several asset pricing models, with the CAPM being the most widely used. However, this single-factor model has low explanatory power and low prediction accuracy on private-equity timberland. It also fails to consider time variation in expected returns and does not capture risk of unfavorable shifts in the investment opportunity set. In contrast, multi-factor models such as the Fama-French three-factor model, the arbitrage pricing theory, and the intertemporal CAPM can better explain the financial characteristics of timberland and other assets (Sun and Zhang 2001; Yao et al. 2014). In addition to expected returns, volatility of returns is another important characteristic affecting investment decision. In measuring and forecasting volatility of timberland returns, a GARCH model is often used together with various asset pricing models.

Timber REITs own and manage a significant area of commercial timberlands in the US. Acquisitions of high-quality industrial timberland and their sustainable management is one of the major business strategies of all timber REITs. For instance, CatchMark acquired 0.4 million ha of East Texas timberland in a joint venture in 2018; Weyerhaeuser purchased around 27,923 ha of highly productive timberlands in the southwest Alabama in 2021. Timber REITs are likely to pursue more timberland acquisitions in the future for cash flow generation, portfolio enhancement, and improvement of the long-term enterprise values. With the increasing concerns over climate change and carbon sequestration, timber REITs are strategizing to capitalize emerging carbon opportunities. Although future legislations about clean energy or carbon emissions are uncertain at this time, timber REITs should anticipate some effects of those legislations on their timberland operations.

More restructuring activities may take place in the form of mergers and acquisitions that enhance synergy and reduce risk. Currently, lumber prices are soaring to a record-high due to the interaction between a high demand from the housing market and a low supply from timber producers. Given that the lumber prices tend to lead timber REIT returns, surge in lumber prices may have even greater impact on timber REIT prices and performances. Looking forward, we expect more research on the financial performance of timber REITs and their comparisons with other types of real estate.

Acknowledgements

United States Department of Agriculture Grant GEOZ-0199-MS partially funded this research.

Table 2.1. Publicly traded timber real estate investment trusts (REITs) in the US.

Timber REITs	Inception year	Acreage (mm ha)	Land location	Total assets (mm $)	Total revenue (mm $)	Net income (mm $)	Market capitalization (billion $) *
Rayonier	2004	1.1	10 states	3728	859	37	4.2
PotlatchDeltic	2006	0.7	6 states	23	1040	166	2.9
Weyerhaeuser	2010	4.3	18 states	16,311	7532	797	22.5
CatchMark	2014	0.2	5 states	607	104	(17)	0.5

Note: Data come from company websites or 2020 10-K reports. Outside the US, Rayonier and Weyerhaeuser manage 0.2 million ha and 5.7 million ha of timberlands in New Zealand and Canada respectively.

* Stock price times total shares outstanding as of 31 December 2019 (WRDS 2020).

Table 2.2. Tree species distribution in different timberland regions of timber real estate investment trusts (REITs).

Timber REITs	Regions	Species
Rayonier	South	Two-third of the land is dominated by pine plantations such as loblolly and slash pine. Remaining one-third consists of natural pine and a variety of hardwood species. Around 67% of timberlands are planted or plantable in this region.
	Pacific Northwest	Consists primarily of Douglas-fir and western hemlock. Other species include western red cedar (softwood species) and red alder (natural hardwood). Around 77% of timberlands are planted or plantable in this region.
PotlatchDeltic	North	Consists of softwood species such as Douglas-fir, grand fir, and inland red cedar. Other species include ponderosa pine, western white pine, aspen, red pine, and hardwoods.
	South	Southern timberlands comprise of southern yellow pines and hardwoods.
Weyerhaeuser	North	Comprises a mix of temperate broadleaf hardwoods (60% of inventory) and mixed conifer species (40% of inventory) that include American beech, birch, cedar, maple, cherry, hemlock, oak, spruce, red and white pine.
	South	Around 76% of standing inventories are southern yellow pines and remaining 24% are hardwoods.
	West	Timberlands in the west are dominated by Douglas-fir and cedar (roughly 79% of inventory). Other species include noble-fir, ponderosa pine, red alder, western larch, Sitka spruce etc.
CatchMark	South	Comprises primarily of pine plantations (more than 72%) and a mix of natural pine and hardwoods.
	Pacific Northwest	Consists of 87% of commercial conifers and 90% of productive areas.

Note: Information about species distribution comes from 2020 10-K reports of each timber REIT.

Table 2.3. List of reviewed journals that published articles related to real estate investment trusts.

Research field	Journals	Number of articles
Forestry	*Forest Policy and Economics*	10
	Journal of Forestry	4
	Forest Science	3
	Journal of Forest Economics	3
	Canadian Journal of Forest Research	2
	Forest Products Journal	2
	Others (with single publication) *	4
Real estate, finance, and economics	*Journal of Real Estate Portfolio Management*	3
	Journal of Real Estate Research	2
	Others (with single publication) *	9
Total		42

* Journal details are in the reference section.

Table 2.4. Summary of methodologies employed in the financial analysis of timber REITs.

Methodology	Reference	Timber REIT data	Major findings
Event study analysis	Mendell et al. (2008)	Daily stock prices of PCL, RYN, LFB, and PCH for the event period of 11 days	Statistically significant positive abnormal returns.
Parametric (CAPM and Fama-French three-factor models) and nonparametric (Stochastic Discount Factor) approaches	Mei and Clutter (2010); Mei (2017)	Quarterly returns of PCL, PCH, and RYN from 1987Q1 to 2008Q4, annual unleveraged returns of PCL, RYN, PCH, and WY from 2010 to 2014	High excess returns and performed similarly as the market, lower return and higher risk of public timber companies than pure-play index.
Mean-variance approach	Scholtens and Spierdijk (2010)	Quarterly returns of PCL, RYN, and PCH from 1994Q4 to 2007Q3	No significant improvement in the mean-variance frontier.
CAPM under inflation, and Fama-French three-factor model	Wan et al. (2013)	Quarterly returns of PCL, RYN, PCH, and WY from 1987Q1 to 2009Q4	Improvement in hedging ability of forest products companies after REIT conversions.
Entropy measurement	La and Mei (2013)	Daily returns of PCL, RYN, PCH, and WY from July 1999 to December 2012	Less efficient to incorporate information than forest products industries and S&P 500.
Event study analysis and GARCH	Sun et al. (2013)	Daily returns of PCL, RYN, LFB, PCH, and WY between 1997 and 2010	Increased volatility and statistically significant abnormal returns for REIT conversion announcements.
GARCH and extreme value models	Sun (2013a); Sun (2013c)	Daily returns and trading volumes of PCL*, RYN, and PCH between 1999 to 2010	Positive return-volume relation, high value at risk during the recession.
Copula modeling	Sun (2013b)	Daily returns of PCL, RYN, LFB, PCH, and WY from 3 March 1994 to 31 December 2010	Smaller volatility of tail dependence, fewer diversification potential.
CAPM and APT	Yao et al. (2014)	Quarterly value weighted returns of PCL, RYN, PCH, and WY from 1988Q1 to 2011Q4	Higher mean excess returns of public equity timberland assets, more variations in returns explained by APT than the CAPM.
Intertemporal CAPM	Yao and Mei (2015)	Quarterly returns of PCL, RYN, PCH, and WY from 1988Q1 to 2011Q4	More variations in cross-sectional returns explained by intertemporal CAPM, significant positive excess returns for public-equity timberland assets over 1988–1999.
Co-integration analysis	La and Mei (2015)	Daily prices of PCL, RYN, PCH, and WY from December 2009 to December 2013	Long-run diversification potential.

BDS independence test and bootstrapping method	Mei (2015a)	Quarterly returns of PCL, RYN, PCH, and WY from 1987Q1 to 2012Q4	Independent and identically distributed public-equity timberland asset returns, average periodic return and risk remain almost constant.
Regression-based and pure-play approaches	Mei (2015b)	Monthly returns of PCL, RYN, PCH, and WY from 2010 to 2014	Pure-play index better depicts returns on securitized timberland assets.
Intertemporal CAPM and multivariate GARCH	Piao et al. (2016)	Daily returns of PCL, RYN, PCH, and WY from 4 January 1999 to 31 December 2014	Intertemporal CAPM more capable in explaining cross-sectional returns of timber REITs. Larger market capitalization, no excess returns, and insensitive to recessionary shocks.
Buy-and-hold AR, cumulative AR**, zero-investment portfolio approach with rolling regression***, and panel data regression	Piao et al. (2017)	Monthly financial data of PCL, RYN, PCH, and WY for event period of one to three years	Statistically significant abnormal returns in the long term.
Vector error correction model and GARCH	Clements et al. (2017)	Lumber futures contract prices and quarterly prices of PCL, RYN, PCH, and WY from 1999Q3 to 2014Q4	Positive long-run and short run relationship between lumber futures and timber REITs.
Augmented CAPM and bivariate vector autoregression model	Mei and Clutter (2020)	Quarterly returns of RYN, PCH, WY, and CTT from 1999Q1 to 2017Q4	Insignificant positive abnormal returns, REIT returns predict TIMO returns, and higher systematic risk of timber REITs.
Mean variance approach and mean conditional value-at-risk	Restrepo et al. (2020)	Annualized returns of RYN, PCH, WY, and CTT from 1987 to 2018	Weight on timberland in the mixed-asset portfolio vary with time.

Note: PCL = Plum Creek, RYN = Rayonier, LFB = Longview Fiber, PCH = PotlatchDeltic, WY = Weyerhaeuser, CTT = CatchMark.

REIT = Real Estate Investment Trusts, TIMO = Timberland Investment Management Organizations.

CAPM for capital asset pricing model, APT for arbitrage pricing theory, GARCH for generalized autoregressive conditional heteroscedasticity model, and AR for abnormal return.

* PCL was analyzed separately as Master Limited Partnerships and timber REIT.

** Based on the CAPM.

*** Based on the Fama-French three-factor model.

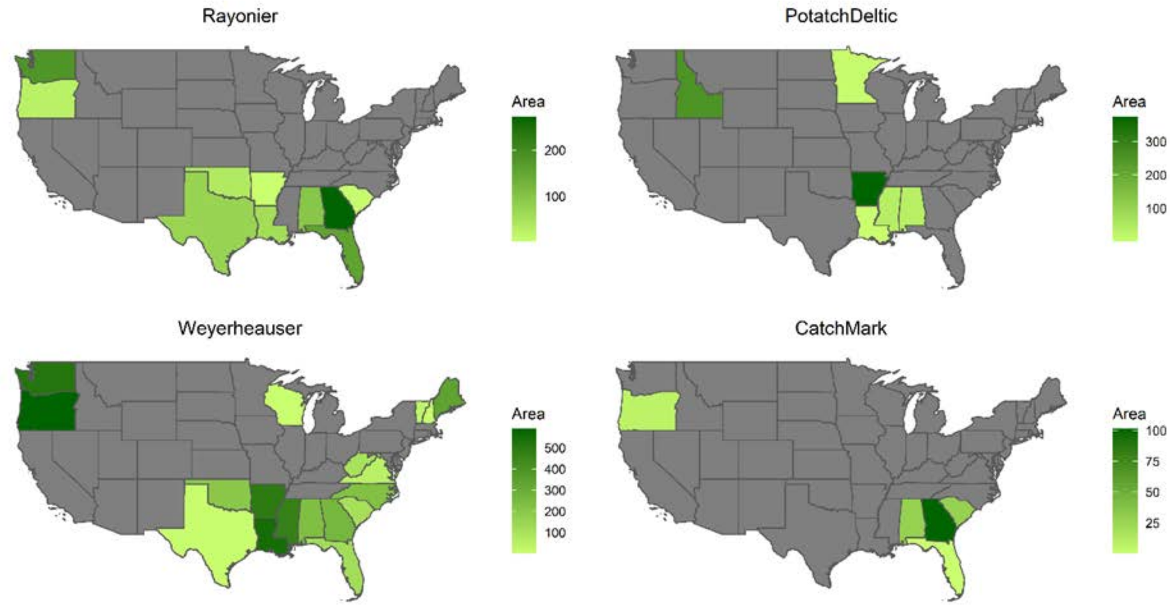

Figure 2.1. Area of timberlands in thousands of hectares (shades of green) managed by current timber real estate investment trusts (REITs) in different states of the US. Rayonier and CatchMark have largest timberlands in Georgia (272.4 ha and 101.2 ha) and smallest in Arkansas (2.4 ha) and Florida (0.2 ha) respectively. PotlatchDeltic holds largest timberlands in Arkansas (373.8 ha) and smallest in Louisiana (2.4 ha). Weyerhaeuser has largest timberlands in Oregon (588.5 ha) and smallest in Wisconsin (1.2 ha). State level timberland data come from 2020 10-K reports of each timber REIT (CatchMark 2020; PotlatchDeltic 2020; Rayonier 2020; Weyerhaeuser 2020) and shapefiles for the US States come from 'maps' package in R programming language (Becker and Wilks 2018).

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CHAPTER 3

The time-varying link of public timber REITs with private timberland, real estate, and financial assets[3]

[3] Baral, S. and B. Mei. 2022. Submitted to *Forest Science*, 12/13/2021.

Abstract

We examine the relationship between public timber real estate investment trust (REIT), private timberland, real estate, and financial asset returns using a multi-factor model and investigate the time-varying volatility of timber REITs under the state space framework. We first orthogonalize explanatory variables to obtain pure factors. Then, we decompose REIT volatility into S&P500, private-equity timberland, real estate, bond, and idiosyncratic risk components. Results reveal that timber REITs are positively sensitive to S&P500 and bonds. Volatility contribution of S&P500 is consistent and high whereas that of idiosyncratic risk declines over time. Other factors, private-equity timberland, real estate, and bond, exhibit negligible contribution to the volatility of timber REITs. We conclude that timber REIT characteristics change with time and the timber REIT market is not mature.

Study Implications

Understanding the return dynamics and time-varying risk decomposition of timber real estate investment trusts (REITs) are critical for institutional investors, portfolio managers, and those interested in timberland investments. Timber REIT return is sensitive to those on other major asset classes and so is timber REIT volatility. Our analysis has implications on: (i) asset allocation in a mixed-asset portfolio, (ii) portfolio risk management under various market conditions, and (iii) portfolio rebalancing strategy. Overall, this study improves our understanding of timber REIT characteristics and market maturity, thereby offering practical implications in portfolio construction, evaluation, and optimization that involves timber REITs.

Introduction

Timberland investment involves the acquisition, management, and disposition of forestland for producing financial return. Over the past two decades, timberland has gained popularity as an alternative asset class due to its distinct financial characteristics such as high risk-adjusted return (Mei 2017), portfolio diversification potential (Wan et al. 2015; Restrepo et al. 2020), and inflation hedging ability (Wan et al. 2013). In the US, industrial timberland is primarily held by timberland investment management organizations (TIMOs) and public timber real estate investment trusts (REITs). TIMOs manage timberland on behalf of the investors whereas timber REITs own and manage income producing timberland, thereby offering higher liquidity and tax efficiency. As of 2020, there are four timber REITs in the US that control over 17 million acres of timberlands valued at about $34 billion by market capitalization (WRDS 2020; Baral and Mei 2021).

Several studies have investigated the financial performance of timber REITs from their risk and return profiles. For example, Sun (2013a) investigates the risk of timber REITs during the 2008 recession period and finds a daily loss up to 13% of investments during the volatile period. Sun (2013b) shows the serial correlation and heteroskedasticity issues associated with return and volatility series of timber REITs and demonstrates a positive risk-return relationship. La and Mei (2013) quantify the informational efficiency of timber REITs and find that they are less efficient than the S&P500 index, offering better arbitrage opportunities. Piao et al. (2016) compare the performance of timber REITs with other specialized REITs and traditional REITs and reveal least sensitivity of timber REIT return to recessionary shocks whereas high vulnerability to idiosyncratic shocks.

Another stream of research examines linkages between timber REIT and financial asset returns and reveals mixed results. Sun (2013c) concludes that timber firms become highly receptive to market fluctuations after REIT conversions as they are dependent on the overall stock market performance. Piao et al. (2016) and Mei and Clutter (2020) report similar results showing high systematic risk and limited portfolio diversification ability of timber REITs. Mei (2017) finds no superior performance of timber REITs on a risk-adjusted basis and claims that timber REITs behave like large-cap stocks. However, La and Mei (2015) find no cointegration between timber REITs and S&P500 index and reveal long-run diversification benefits. The mixed results observed in above studies could be attributable to different sampling periods and methods used in evaluating the performance of timber REITs.

Regarding the relationship between timber REIT and private-equity timberland, Mei (2015) reveals that the public timber market tends to lead the private market by one quarter. Mei and Clutter (2020) confirm this result after making adjustments in the return data with regard to financial leverage, management fees, geographic distribution, and non-timber business segments of REITs. Due to higher liquidity and transparency of timber REITs, new information is first reflected in the timber REIT market. Thus, the price formation of TIMOs tend to depend on the information flow from timber REITs. Similar information flow is evidenced in the real estate sector as well (Barkham and Geltner 1995; Ling and Naranjo 2015).

Only a few studies have examined timberland and commercial real estate assets together (Waggle and Johnson 2009; Mei et al. 2020). Waggle and Johnson (2009) evaluate the roles of commercial real estate and timberland in a portfolio consisting of financial assets and find that commercial real estate entered low-risk portfolios, whereas timberland entered all portfolios. Mei et al. (2020) investigate the information flow among timberland and commercial real estate in the private market and find one-way information transition from the timberland to the real estate market. They suggest that current commercial real estate returns can be predicted with lagged timberland returns during certain market conditions. Like the commercial real estate, timber REITs generate some cash flows and earnings from their real estate properties and often use substantial financial leverage. With economic growth and interest rate being some of the common performance drivers of timber REITs and commercial real estate, there might be some relationships between these two markets (Mei et al. 2020).

In summary, past studies suggest a fundamental link between timber REITs, financial assets, real estate assets, and private-equity timberland. There may be some underlying state variables that are common to timber REITs and other asset classes. Therefore, understanding their effects on timber REIT returns have become very important. Although several studies have assessed the characteristics of timber REIT returns from various aspects and discussed their relationship with other major asset classes (e.g., behave like large-cap stocks), this study provides some additional evidence and another perspective on the time-varying risk-return relationship of timber REITs. Specifically, we aim to examine the sensitivity of timber REIT returns to those on private-equity timberland, commercial real estate, and financial assets. Further, we perform a rigorous decomposition of timber REIT volatility, which allows us to identify its determinants.

Timber REIT return dynamics are often evaluated by single- and multi-factor asset pricing models (Mei 2019; Baral and Mei 2021). Such models restrict parameter estimates to be constant that may not be plausible from an economic and financial standpoint in explaining the market integration. Additionally, the modern portfolio theory is commonly used to compare timberlands with other assets (Wan et al. 2015). However, there are several weaknesses of this technique that makes it less desirable to portfolio managers. Lee (2020) argues that time-varying nature of market integration should be considered to reveal shifts in return dynamics and to avoid misleading interpretations. Hence, we employ the state space framework with a Kalman filter for a more accurate investigation of the return and volatility of timber REITs.

Data

To examine the sensitivity of timber REIT returns to other asset returns, we consider four asset classes including large-cap stocks, AAA corporate bonds, commercial real estate, and private-equity timberland. Returns on large-cap stocks and bonds are proxied by the S&P 500 value-weighted returns (S&P500) and the long-term AAA corporate bond yield (LTC), respectively (Moody's 2020). Returns on commercial real estate are approximated by the National Council of Real Estate Investment Fiduciaries (NCREIF) property index (NPI), which measures the performance of income producing commercial real estate properties (FTSE 2020). As of 2020Q4, NPI consisted of 9,289 properties with a total market value of over $700 billion (Corgel 2021). As NPI is subject to a number of limitations, we employ NCREIF transaction-based property index (NTBI)[4].

Returns on private-equity timberland are proxied by the NCREIF timberland index (NTI), which measures the gross returns of investment-grade timberland properties. As of 2020Q4, NTI consisted of 460 timberland properties with a total market value of more than $22 billion (NCREIF 2020). NTI is reported quarterly and is considered as the best benchmark for tracking the performance of private-equity timberland. However, NTI is subject to appraisal smoothing

[4] NPI may not reflect the actual market conditions because of the appraisal smoothing and the inclusion of stale values. As a result, the index may not reflect the market behavior precisely.

bias as it is based on the appraisal values. To account for this bias, we use unsmoothed NTI (uNTI) (Mei 2017).

Returns on public-equity timberland (PUBLIC) are approximated by the value-weighted quarterly returns on a dynamic portfolio of public timber firms in the US (Mei and Clutter 2010). Over time, the portfolio includes Plum Creek, Rayonier, Potlatch, Weyerhaeuser, CatchMark, Deltic Timber, The Timber Co., IP Timberlands Ltd., and Pope Resources. Public timber companies manage around 19 million acres of timberland with a market value over $29 billion in the US (Mei and Clutter 2020). Rayonier, PotlatchDeltic, Weyerhaeuser, and CatchMark are the current timber REITs. Plum Creek became the first timber REIT in 1999 but was later acquired by Weyerhaeuser in 2016. Rayonier bought Pope Resources in 2020 and Potlatch took over Deltic Timber in 2018. Prior to those acquisitions, Pope Resources was a limited partnership and Deltic Timber was a C-Corp. The Timber Co. and IP Timberlands Ltd. were subsidiaries of Georgia-Pacific and International Paper, which sold their timberlands in 2001 and 2006 respectively. Returns are value weighted by market capitalization. These data are obtained from the Center for Research in Security Prices (WRDS 2020). We use quarterly returns from 2000Q1 to 2019Q4 for all assets so as to match the availability of timber REIT data.

Methods

Asset Return Evaluation

Considering the potential influences of unobservable state variables, which are common to timber REITs and other asset classes, we employ a multi-factor linear model

$$r_{TREITt} = \beta_0 + \beta_1 r_{SP500t} + \beta_2 r_{uNTIt} + \beta_3 r_{NTBIt} + \beta_4 r_{LTCt} + u_t \qquad (1)$$

where r_{TREITt} is the return on timber REITs, r_{SP500t} is the return on large-cap stocks proxied by the S&P 500 index, r_{uNTIt} is the unsmoothed return on private-equity timberland, r_{NTBIt} is the return on commercial real estate, and r_{LTCt} is the return on long-term AAA corporate bonds, all at time *t*. Coefficient $\beta's$ measure the effects of various asset returns on timber REIT returns, and u_t is the error term or the idiosyncratic factor. In equation (1), unobservable state variables are proxied by S&P500, uNTI, NTBI, and LTC.

Before estimating equation (1), we check the correlations among all return indices as they may have some common underlying state variables. To correctly gauge the marginal effects and to address the problem of multicollinearity, we estimate equation (1) in a two-step regression process, a method previously used by Clayton and MacKinnon (2003). In the first step, we perform "orthogonalizing" regressions to obtain "pure" factors that are uncorrelated with each other. This allows us to decompose volatility of timber REITs into stock, private timberland, real estate, bond, and idiosyncratic components. Specifically, we conduct a series of regressions in which each independent variable in equation (1) are specified as a linear function of other independent variables and use the residuals as the orthogonal (pure) factors of each asset class. i.e.,

$$r_{NTBIt} = \delta_0 + \delta_1 r_{SP500t} + \delta_2 r_{uNTIt} + \delta_3 r_{LTCt} + \varepsilon_{NTBIt} \tag{2}$$

where ε_{NTBIt} is a pure real estate factor that is not influenced by other asset classes. Then, we use the residuals in equation (2) to determine a pure bond factor as

$$r_{LTCt} = \gamma_0 + \gamma_1 r_{SP500t} + \gamma_2 r_{uNTIt} + \gamma_3 \hat{\varepsilon}_{NTBIt} + \varepsilon_{LTCt} \tag{3}$$

where ε_{LTCt} represents a pure bond factor, which is orthogonal to pure real estate and other asset classes. Similarly, we construct a pure private timberland factor from the following regression

$$r_{uNTIt} = \varphi_0 + \varphi_1 r_{SP500t} + \varphi_2 \hat{\varepsilon}_{NTBIt} + \varphi_3 \hat{\varepsilon}_{LTCt} + \varepsilon_{uNTIt} \tag{4}$$

where ε_{uNTIt} represents a pure private timberland factor. As such, the S&P500 acts as the numeraire or base because residuals from equations (2), (3), and (4) are uncorrelated with it. In other words, S&P500 is used as an independent variable in all first-step regressions. In the second step, we use the pure factors generated in the previous step to estimate equation (1) as

$$r_{TREITt} = \beta_0 + \beta_1 r_{SP500t} + \beta_2 \hat{\varepsilon}_{uNTIt} + \beta_3 \hat{\varepsilon}_{NTBIt} + \beta_4 \hat{\varepsilon}_{LTCt} + \mu_t. \tag{5}$$

Volatility Decomposition

We decompose the volatility of timber REIT returns into components related to each individual asset class. By using estimates from equation (5), the return volatility identity equation can be expressed as

$$Var[r_{TREIT}] \equiv \sigma^2{}_{TREIT} = \beta_1^2 \sigma^2{}_{r_{SP500}} + \beta_2^2 \sigma^2{}_{\varepsilon_{uNTI}} + \beta_3^2 \sigma^2{}_{\varepsilon_{NTBI}} + \beta_4^2 \sigma^2{}_{\varepsilon_{LTC}} + \sigma_u^2 \tag{6}$$

Based on equation (6), we calculate the relative contribution of each factor to the total volatility of timber REIT return by the following equations:

$$\text{Stock market} = \frac{\beta_1^2 \sigma^2{}_{r_{SP500}}}{\sigma^2{}_{TREIT}}$$

$$\text{Private-equity timberland} = \frac{\beta_2^2 \sigma^2{}_{\varepsilon_{uNTI}}}{\sigma^2{}_{TREIT}}$$

$$\text{Real estate} = \frac{\beta_3^2 \sigma^2{}_{\varepsilon_{NTBI}}}{\sigma^2{}_{TREIT}}$$

$$\text{Bond} = \frac{\beta_4^2 \sigma^2{}_{\varepsilon_{LTC}}}{\sigma^2{}_{TREIT}}$$

$$\text{Idiosyncratic} = \frac{\sigma_u^2}{\sigma^2{}_{TREIT}}\,. \tag{7}$$

State Space Model with Time-Varying Parameters

Equations (1) and (6) can be estimated by the ordinary least squares, in which parameter estimates are imposed to be constant, implying a constant relationship between timber REITs and other assets. However, this may be unrealistic in the real world. Hence, we use the state space framework with a Kalman filter to examine the changing pattern of timber REIT return volatility over the past 20 years.

Two stages are involved in capturing the time-varying trend of return volatility. In the first stage, the state space framework is specified. A general state space form for a multivariate linear model can be represented as

$$\mathbf{y}_t = \mathbf{Z}_t\boldsymbol{\alpha}_t + \boldsymbol{\varepsilon}_t, \qquad \boldsymbol{\varepsilon}_t \sim NID(\mathbf{0}, \mathbf{H}_t) \tag{8}$$

where t = 1,……, N, $\mathbf{y}_t$ is a N × 1 vector of observed values at time t, $\mathbf{Z}_t$ is a $N \times m$ matrix of variables, $\boldsymbol{\alpha}_t$ is an m × 1 state vector, $\boldsymbol{\varepsilon}_t$ is an N × 1 serially uncorrelated error term vector with mean zero and covariance matrix $\mathbf{H}_t$. Equation (8) is known as the observation or measurement equation. The state or transition equation can be represented as

$$\boldsymbol{\alpha}_t = \mathbf{T}_t\boldsymbol{\alpha}_{t-1} + \mathbf{R}_t\eta_t, \qquad \eta_t \sim NID(\mathbf{0}, \mathbf{Q}_t) \tag{9}$$

where $\mathbf{T}_t$ is a $m \times m$ transition matrix, $\mathbf{R}_t$ is a $m \times g$ selection matrix, and η_t is a g × 1 serially uncorrelated error term vector with mean zero and covariance matrix $\mathbf{Q}_t$.

In the second stage, a Kalman filter is applied to estimate the state space model that we formulated in the first stage. Kalman filter is a recursive algorithm that calculates the optimal estimator of state vector at time t by updating the information of the system as new observation y_t becomes available. The updating equations for each time period include

$$\boldsymbol{\vartheta}_t = \mathbf{y}_t - \mathbf{Z}_t\boldsymbol{\alpha}_{t-1}$$

$$\mathbf{F}_t = \mathbf{Z}_t\mathbf{P}_t\mathbf{Z}_t' + \mathbf{H}_t$$

$$\mathbf{K_t} = \mathbf{T_t P_t Z_t' F_t^{-1}}$$

$$\mathbf{L_t} = \mathbf{T_t} - \mathbf{K_t Z_t} \tag{10}$$

$$\boldsymbol{\alpha}_\mathbf{t} = \mathbf{T_t}\boldsymbol{\alpha}_\mathbf{t-1} + \mathbf{K_t}\boldsymbol{\vartheta}_\mathbf{t}$$

$$\mathbf{P_t} = \mathbf{T_t P_{t-1} L_t'} + \mathbf{R_t Q_t R_t'}$$

where $\boldsymbol{\vartheta}_\mathbf{t}$ is the one step ahead prediction error and $\mathbf{F_t}$ is its variance, $\mathbf{P_t}$ is the covariance matrix for the state vectors, and $\hat{\alpha}_t$ is the optimal state vector value. The initial state vector can be specified as $\boldsymbol{\alpha}_\mathbf{0}$ and $\mathbf{P_0}$ (Harvey 1989; Sun 2007; Mei and Clutter 2010)[5].

Using the multi-factor model defined in equation (5), we specify the system of equations in the state space framework as

$$r_{TREITt} = \beta_0 + \beta_{1t} r_{SP500t} + \beta_{2t}\hat{\varepsilon}_{uNTIt} + \beta_{3t}\hat{\varepsilon}_{NTBIt} + \beta_{4t}\hat{\varepsilon}_{LTCt} + u_t$$

$$\beta_{1t} = \beta_{1,t-1} + \eta_t$$

$$\beta_{2t} = \beta_{2,t-1} + \tau_t \tag{11}$$

$$\beta_{3t} = \beta_{3,t-1} + \gamma_t$$

$$\beta_{4t} = \beta_{4,t-1} + e_t$$

The first line in equations (11) is the observation equation and the rest are the state equations. Here, each state variable follows a random walk. We use the *KFAS* package, version 1.4.6 in the R programming language in estimating the state space model because it includes computationally efficient functions for Kalman filtering in R (Helske 2021).

State space is a well-established mathematical framework that captures external shocks such as changes in policy and economic reforms into the system (Sun 2007). One advantage of Kalman filter is that it can predict measurements in a recursive way so that the information can

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[5] Harvey (1989) and Sun (2007) provide detail information about the filtering and updating equations.

be updated into the system when a new measurement becomes available. It has been applied to a variety of forestry-related issues, including policy analysis (Sun 2007), financial performance of timberland investments (Mei and Clutter 2010), Landsat image analysis (Sedano et al. 2014), and monitoring forest defoliation and other forest disturbances (Olsson et al. 2016; Ye et al. 2021). Kalman filter is considered as one of the best classes of linear filters and has a great potential in forest finance and economics research (Pasricha 2006).

Empirical Results

Descriptive Statistics

A historical trend of the return indices (2000Q1 to 2019Q4) is illustrated in Figure 3.1. There are some contrasting patterns over time. NTBI and uNTI mostly fluctuate around zero and are relatively less volatile in current years. Compared with NTI, uNTI has more volatility. S&P500 and PUBLIC exhibit much more variability than other return indices, and PUBLIC closely follows S&P500. LTC is mostly positive and shows the lowest volatility among all the return indices. We also observe some common themes across these return indices. For instance, most indices respond to the financial crisis around 2008. However, uNTI tends to lag PUBLIC by about one year as evidenced by Mei (2017) and Mei and Clutter (2020).

Table 3.1 shows the summary statistics of all the return indices from 2000Q1 to 2019Q4. The average quarterly returns are 2.35% for PUBLIC, 1.21% for S&P500, 1.43% for uNTI, 2.41% for NTBI, and 1.25% for LTC. NTBI has the highest mean and a moderate standard deviation of 4.85%. NTBI and PUBLIC are very similar in the mean, but PUBLIC has a higher risk of 11.57%. Although S&P500, uNTI, and LTC show roughly the same mean, LTC exhibits a much lower risk than the other two indices. In contrast to public-equity timberland, private-equity timberland has a lower mean return and a lower risk. Regarding the correlations, PUBLIC is strongly, positively correlated with S&P500 (0.6885) but weakly, negatively correlated with other return indices. All other return indices have weak negative correlations with each other except between uNTI and NTBI. uNTI exhibits a weak positive correlation of 0.1239 with NTBI. Overall, the correlation results prove the presence of some common state variables that influence the return generating processes of the selected asset classes.

Multi-Factor Model Results

Table 3.2 reports the estimation of the sensitivity of timber REIT returns to orthogonalized uNTI, NTBI, and LTC factors with S&P500 as the numeraire. The estimates for financial factors are positive whereas those for private-equity timberland and real estate factors are negative. The small negative estimates of private-equity timberland and real estate factors suggest insensitivity of timber REIT returns to those indices. Among the financial factors, LTC has the highest coefficient estimate. However, S&P500 is the only factor that exhibits a significant influence on timber REIT returns over the chosen sample period. The moderately high R^2 shows that the orthogonalized factors can explain nearly 50% of the variation in timber REIT returns. Overall, the results suggest that timber REITs and the selected financial assets are influenced by some common state variables.

Based on the estimates in Table 3.2, we quantify the contributions of S&P500, uNTI, NTBI, LTC, and idiosyncratic factors on timber REIT volatility (Table 3.3). With S&P500 as the numeraire, the factors associated with stocks and bonds explain about 46% and 1% of timber REIT volatility, respectively. Private-equity timberland and real estate factors, on the other hand, do not explain the variation in timber REIT returns much. Idiosyncratic risk is by far the largest contributor (53%) to timber REIT volatility. However, the respective proportions of the volatility explained by these components may change over time. In the next section, we explore the time-varying effect of individual asset on timber REIT return and volatility.

State Space Estimation Results

Figure 3.2 reports the breakdown of the time-varying proportion of timber REIT volatility due to S&P500, uNTI, NTBI, LTC, and the idiosyncratic risk factor. The top portion shows that uNTI, NTBI, and LTC follow a similar trend in explaining timber REIT volatility in the whole sample period. Out of these three factors, uNTI exhibits a negligible volatility contribution. NTBI and LTC exhibit small effect most of the time, but their contribution rises somewhat in the late 2000s to roughly 40% and 25%, respectively.

The bottom portion shows the time-varying contribution of S&P500 and the idiosyncratic risk factor to timber REIT volatility in the early and late 2000s. For example, the contribution of S&P500 drops from roughly 100% in 2000 to almost 0% the following year but rise again to the previous level in 2003. A similar trend is observed later between 2008 and 2011. Overall, the idiosyncratic risk factor contributes more to timber REIT volatility in the earlier years. However, the trend has reversed in the recent years. Beginning 2012, S&P500 plays a greater role in explaining timber REIT volatility with a consistent contribution of more than 65%. That of the idiosyncratic risk, on the other hand, has drastically decreased with a maximum contribution roughly at 35%. Overall, we observe a relatively steady trend of volatility decomposition in the later period of the sample with S&P500 being the dominant contributor. While the importance of S&P500 in explaining timber REIT volatility is increasing significantly over time, that of the idiosyncratic risk is substantially diminishing.

Discussion and Conclusions

Because of historically low interest rates and high volatility in public equity market, institutional investors are interested in adding real estate assets into their portfolios. Timberland has the potential of generating higher income than bonds as well as superior risk-adjusted return than stocks (Fu 2016). In this study, we examine the return dynamics and the volatility decomposition of publicly traded timber REITs using a multi-factor return generating approach. First, we orthogonalize the independent variables to obtain pure factors. Then, we apply a multi-factor model to examine the return relationship between timber REITs, private-equity timberland, financial assets, and commercial real estate. Further, we employ the state space framework with a Kalman filter to assess the time-varying volatility decomposition of timber REITs.

Regression results from the orthogonalized returns reveal that REIT returns are sensitive to S&P500 and investment grade corporate bonds whereas insensitive to private-equity timberland and commercial real estate. This suggests that stock and bond related factors play a key role in driving timber REIT returns. As such, including timber REITs in a portfolio may increase the overall risk exposure to the financial market. Volatility decomposition results show that investment grade corporate bonds contribute a negligible fraction to timber REIT volatility while S&P500 and the idiosyncratic risk factor contribute the most. We also find a high idiosyncratic risk of timber REITs, which is consistent with the findings of Piao et al. (2016). Hence, there is a more pronounced effect of stock and industry-level risk factors on pricing timber REITs.

With structural shifts in the timber REIT sector, the proportion of timber REIT volatility attributable to an individual asset class may change over time. Regarding the time-varying volatility decomposition, we find a high contribution of the idiosyncratic risk factor to timber REIT volatility in the earlier years when timber REIT conversions gained popularity. This may be due to an increasing interest in securitized timberland that provides investors an exposure to this special real estate asset class with some tax benefits. Campbell et al. (2001) reported that the "herding" behavior of institutional investors who dominated the stock market might lead to high volatilities in industry-specific stock returns. Thus, the higher contribution of the idiosyncratic factor in the earlier years may indicate more sensitive timber REIT returns to frequently released firm-specific information (Clayton and Mackinnon 2003). In the later phase of the sample period, however, the contribution of the idiosyncratic factor to timber REIT volatility diminishes noticeably and that of S&P500 remains consistently high. Given that there is usually a declining influence coming from the overall stock market as a sector matures (Anderson et al. 2005), we argue that the timber REIT sector is not full-blown yet. Corroborating the findings in Piao et al. (2016) and Mei (2017), we conclude that timber REITs behave more like large-cap stocks. As such, timber REITs may offer limited diversification benefits in a portfolio investment that already includes large-cap stocks.

Timber REITs being an attractive alternative investment vehicle, understanding their return dynamics becomes crucial from a practical perspective. In summary, our results suggest that the risk-return characteristics of timber REITs have been changing over time and that the timber REIT sector is still in its developing phase. Future research can employ higher frequency data on private-equity assets using the approach proposed by Anderson et al. (2005) to further examine the financial features of timber REITs.

Acknowledgements

United States Department of Agriculture Grant GEOZ-0199-MS partially funded this research.

Table 3.1. Descriptive statistics of selected return indices (2000Q1-2019Q4).

	PUBLIC	S&P500	uNTI	NTBI	LTC
Mean	0.0235	0.0121	0.0143	0.0241	0.0125
SD	0.1157	0.0782	0.0641	0.0485	0.0030
Minimum	-0.3787	-0.2256	-0.1752	-0.1699	0.0082
Maximum	0.2480	0.1522	0.2862	0.1789	0.0234
Correlations					
PUBLIC	1.00				
S&P500	0.6885	1.00			
uNTI	-0.0227	-0.0096	1.00		
NTBI	-0.0422	-0.0397	0.1239	1.00	
LTC	-0.0923	-0.2604	-0.0617	-0.0974	1.00

Note: PUBLIC, a portfolio of public timber firms; uNTI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index; NTBI, NCREIF Transaction based Property Index; and LTC, AAA Long-term corporate bond Index.

Table 3.2. Regression estimates of the factor sensitivities of timber REIT returns on other asset returns.

	Constant	S&P500	uNTI	NTBI	LTC
Estimate	0.0112	1.0179	-0.0290	-0.0088	3.5307
	(0.0097)	(0.1229)	(0.1499)	(0.2009)	(3.2867)
p-value	0.249	0.000	0.847	0.965	0.286
R^2	0.4822				
Adjusted R^2	0.4546				
Number of observations	80				

Note: REIT, Real Estate Investment Trusts; uNTI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index; NTBI, NCREIF Transaction based Property Index; and LTC, AAA Long-term corporate bond Index.

Table 3.3. Volatility decomposition of timber REIT return.

Factors	Volatility contribution (%)
S&P500	46.11
uNTI	0.03
NTBI	0.00
LTC	0.81
Idiosyncratic	53.06

Note: REIT, Real Estate Investment Trusts; uNTI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index; NTBI, NCREIF Transaction based Property Index; and LTC, AAA Long-term corporate bond Index.

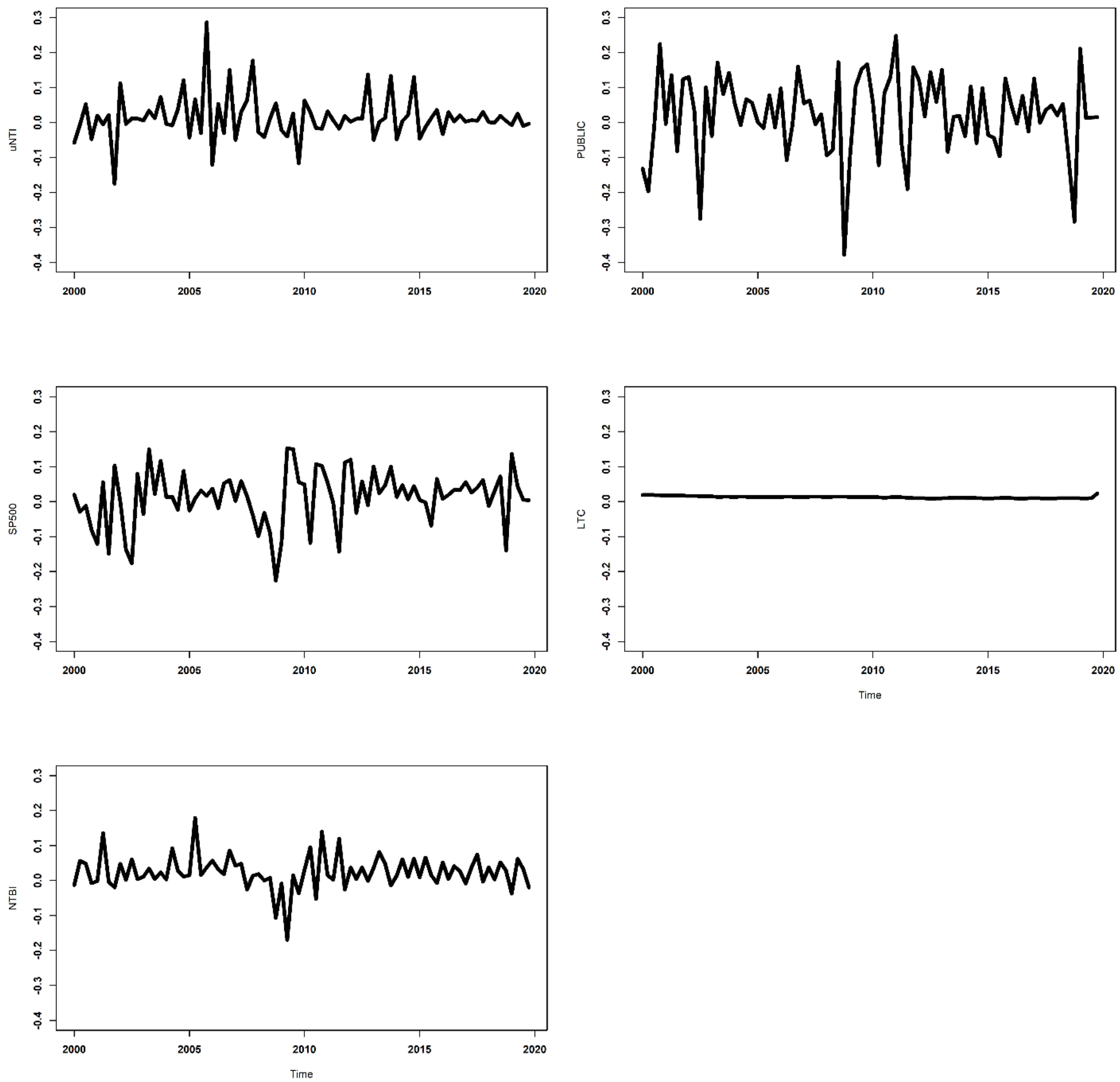

Figure 3.1. Quarterly returns of selected return indices (2000Q1-2019Q4).
Note: PUBLIC, a portfolio of public timber firms; uNTI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index; NTBI, NCREIF Transaction based Property Index; and LTC, AAA Long-term corporate bond Index.

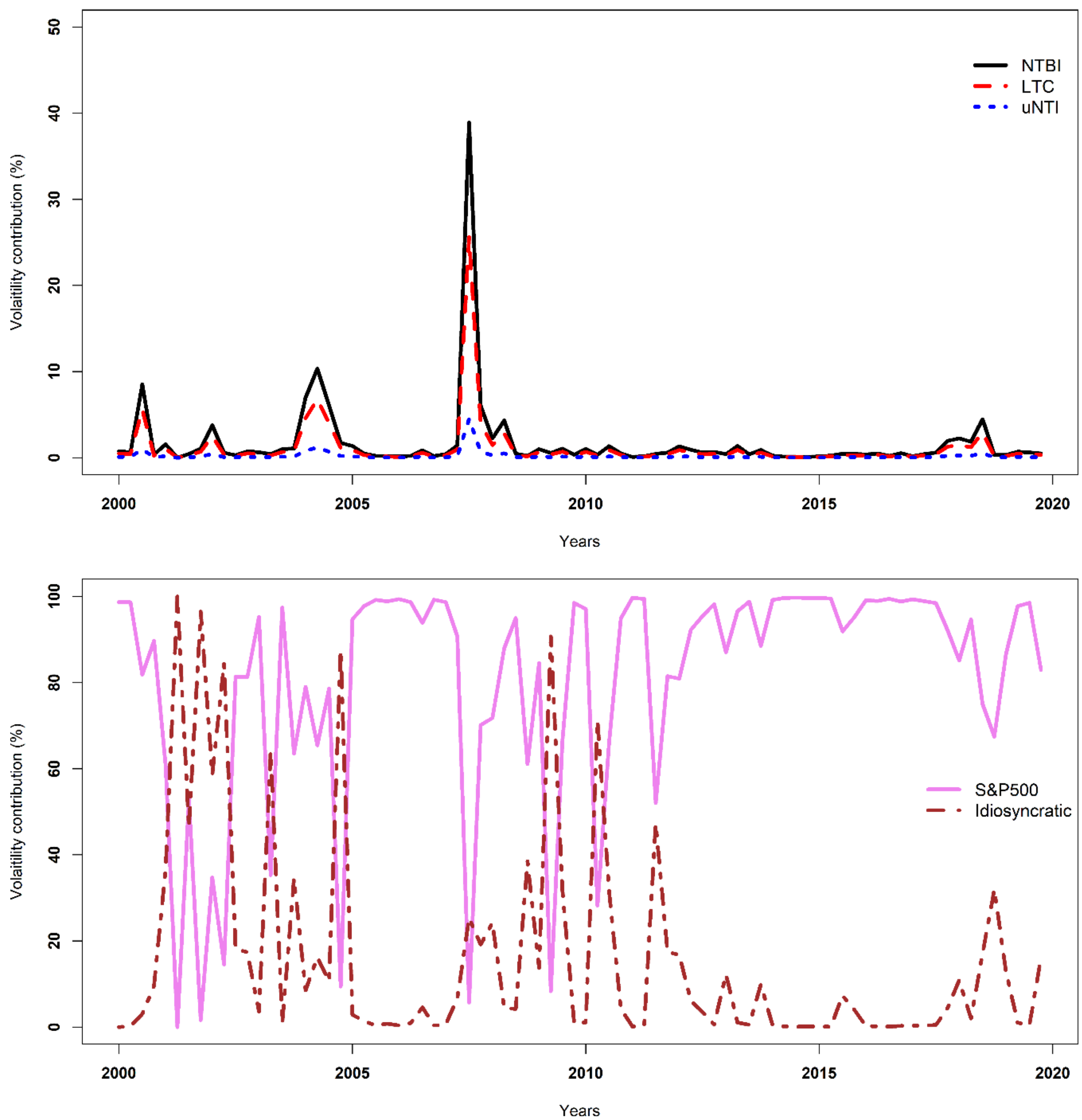

Figure 3.2. Time-varying volatility contributions of S&P500, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index (uNTI), NCREIF Transaction based Property Index (NTBI), AAA long-term corporate bonds (LTC), and idiosyncratic factors to timber REIT return.

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CHAPTER 4

Integration of public farmland and timberland REITs with their private equity counterparties and selected asset classes[6]

[6] Baral, S. and B. Mei. Submitted to *Agricultural Finance Review*, 04/07/2022.

Abstract

Purpose- The purpose of this study is to examine the return sensitivity of public farmland and timberland real estate investment trusts (REITs) to private-equity farmland, timberland and real estate, long-term corporate bonds, and large- and small-cap stocks. We also examine time-dependent contributions of selected asset classes to farmland and timberland REIT volatility.

Design/methodology/approach- We use a multi-factor asset pricing model under a seemingly unrelated regression framework to evaluate farmland and timberland REIT returns, and a state-space model with the Kalman filter to evaluate the time-dependent contributors of farmland and timberland REIT volatility. We first perform orthogonalized regressions to obtain pure independent factors, and then decompose volatility into individual asset components.

Findings- Significant loadings on financial assets are found for both farmland and timberland REITs, suggesting that they are generally driven by some common state variables. Large-cap stocks are found to be the major contributor of farmland and timberland REIT volatility, despite some differing patterns over time.

Originality- Empirical analysis of farmland REIT is very scarce. We compare the risk-return characteristics of farmland and timberland REITs under a state-space framework with the Kalman filter. This study can improve our understanding of the roles of farmland and timberland REITs in a multi-asset portfolio.

Introduction

Real estate investment trusts (REITs) have become an important part of real estate and stock markets as they offer investment opportunities to a broader group of investors by providing shares of often illiquid, capital-intensive real assets. Farmland has gained an increasing interest of investors as a safer alternative asset, particularly during the financial crisis of 2008, due to their strong record of performance, low volatility, and favorable diversification abilities (Kenney, 2010; Lekovic *et al.*, 2018). High farmland transaction costs and liquidity issues supported the emergence of farmland REITs in the US (Stewart, 1994). A farmland REIT is a new investment vehicle that owns a diversified portfolio of farmlands and leases the lands to farmers. As of 2021, there were two public farmland REITs in the US: Gladstone Land and Farmland Partners (Table 4.1). American Farmland was another farmland REIT that was established in 2015 but was acquired by Farmland Partners in 2017. In 2021, the two farmland REITs owned or managed farms in 25 different states with a combined market capitalization of $1.7 billion in US dollars (Lekovic *et al.*, 2018; WRDS, 2021).

Timberland has been well recognized as an attractive asset class that offers high risk-adjusted return, portfolio diversification, and inflation hedging (Mei, 2019). Due to the shift in industrial timberland ownership in the US, separate business segments emerged in the form of timberland REITs and timberland investment management organizations. A timberland REIT is a company that owns or manages timberland and produces income primarily by selling timber. As of 2021, there were four public timberland REITs in the US: Rayonier, PotlatchDeltic, Weyerhaeuser, and CatchMark (Table 4.1), which owned or managed timberlands in 20 different states with a combined market capitalization of around $41 billion (Baral and Mei, 2022; WRDS, 2021). Besides these specialized real estate alternatives, the public commercial real estate market in the US is very large with an estimated market size of $16 trillion (NAREIT, 2022). In addition, the stock and bond markets in the US are the largest in the world with respective market sizes of $52 trillion and $48 trillion as of 2021 (Sifma, 2022).

A number of studies have evaluated the financial performance of farmland within a multi-asset portfolio and produce mixed results. Webb *et al.* (1988) and Lins *et al.* (1992) claim that a substantial allocation of farmland in a multi-asset portfolio provides superior risk adjusted returns. Hardin and Cheng (2002) find the potential of farmland in improving portfolio efficiency only under certainty but not under uncertainty. Hardin and Cheng (2005) confirm that there is a minimal farmland allocation in portfolios that already consist of other real estate investments. Painter (2013) finds that farmland in the North America reduces the risk of diversified portfolios without reducing the expected return. Painter (2015) investigates the risk profile of farmland REITs in the North America and finds that they are low-risk investments than gold, oil, and stock. In contrast, Porter (2019) finds a lower risk-adjusted return of farmland REITs versus direct farmland investment.

Similar to farmland, past studies evaluating the financial performance of timberland REITs within a multi-asset portfolio have mixed results. Sun (2013) examines the dependence of timberland REITs on the equity market and finds limited diversification benefits of timberland REITs. La and Mei (2015) find little evidence of cointegration between timberland REITs and S&P500 index, thereby suggesting some long-run diversification benefits of timberland REITs. However, only a limited number of studies have examined farmland and timberland assets together (Mei *et al.*, 2020; Waggle and Johnson, 2009; Zhang and Mei, 2019). Waggle and Johnson (2009) evaluate the performance of timberland, farmland, and commercial real estate within a multi-asset portfolio and find that timberland enters all portfolios, whereas farmland and commercial real estate only enter low-risk portfolios. Zhang and Mei (2019) find that farmland replaces timberland when risk increases along the efficient frontier. Mei *et al.* (2020) investigate the integration and information transmission between timberland, farmland and commercial real estate markets and find no evidence of integration and a one-way information flow from farmland and timberland to commercial real estate.

Generally speaking, traditional investment portfolios consist of a larger proportion of financial instruments or fixed income securities (Hennings *et al.*, 2005). Yet, the spillover of funds from traditional securities to alternative assets including real estate and private equity was observed in the aftermath of the 2008 financial crisis. Unlike financial securities, specialized real estate assets such as farmland and timberland can provide certain protection against a financial crisis and thus improve a portfolio's performance (Lekovic *et al.*, 2018). For example, the biological growth of trees is not subject to market fluctuations and therefore reduces the volatility of timberland investment returns (Mei *et al.*, 2013). With the rapid development of farmland and timberland REITs, a rigorous analysis of their time-dependent risk-return characteristics and roles in the portfolio optimization are warranted. In contrast to timberland REITs, empirical analyses of the financial performance of farmland REITs are still lacking. Additionally, no study has compared the financial performance of farmland and timberland REITs. Thus, this study aims to evaluate the time-dependent risk-return relationships between farmland and timberland REITs and other asset classes including private-equity farmland, timberland, and commercial real estate, long-term corporate bonds, and large- and small-cap stocks. Results from this study will be of central interest to institutional investors, asset managers, and other stakeholders in the farmland and timberland sectors.

Data

We use quarterly returns of public farmland and timberland REITs, private-equity farmland, timberland, and commercial real estate, AAA corporate bonds, and large- and small-cap stocks. The sample spans from 2013Q1 to 2021Q4 to match the most available farmland REIT data. Returns on public REITs are calculated as the value-weighted portfolio returns of farmland and timberland REITs in the US. Market capitalization of REIT is total shares outstanding times the closing price per share at the end of a month. The portfolio of farmland REITs (FREIT) consists of Gladstone Land Corporation, American Farmland and Farmland Partners. The portfolio of timberland REITs (TREIT) consists of Rayonier, PotlatchDeltic, Weyerhaeuser, and CatchMark. All data are collected from the Center for Research in Security Prices (WRDS, 2021).

Returns on private equity farmland, timberland and real estate are approximated by the corresponding National Council of Real Estate Investment Fiduciaries (NCREIF) indices that measure the gross returns of income producing farmland, timberland and real estate properties in the private market. As of 2020Q4, the NCREIF Farmland Index (NFI) consisted of 1,184 farmland properties with a total market value of $12.3 billion; the NCREIF Timberland Index (NTI) consisted of 460 timberland properties with a total market value of $22 billion; and the NCREIF Property Index (NPI) consisted of 9,289 commercial real estate properties with a total market value of $700 billion (NCREIF, 2020). As NFI, NTI, and NPI are subject to appraisal smoothing bias, we unsmooth these return indices as in Mei (2017). Returns of bonds are proxied by the long-term AAA corporate bond yield (LTC) (Moody's, 2022); returns of large-cap stocks are approximated by the S&P 500 value-weighted returns (SP500); whereas returns of small-cap stocks (SCAP) are approximated by the value-weighted returns of the 10^{th} decile (the smallest) market cap portfolio (WRDS, 2021).

Methods

Return and volatility evaluation

We employ a multi-factor asset pricing model and volatility decomposition methodology similar to Clayton and Mackinnon (2003). First, we perform orthogonalized regressions to address cross influences of private equities, long-term bonds, and large- and small-cap stocks on REIT returns and to decompose return volatility. Specifically, we model the returns of individual asset class as a linear function of the returns of other asset classes. As such, we obtain the residual and use it as pure factor of a specific asset class that is independent to the pure factors of other asset classes. For example, for private-equity real estate, we run a regression of equation (1) as

$$r_{uNPI,t} = \delta_0 + \delta_1 r_{SP500,t} + \delta_2 r_{uPE,t} + \delta_3 r_{LTC,t} + \delta_4 r_{SCAP,t} + \varepsilon_{uNPI,t} \tag{1}$$

Where $r_{uNPI,t}$ is commercial real estate return, $r_{SP500,t}$ is large-cap stock return, $r_{uPE,t}$ is private-equity return, $r_{LTC,t}$ is long-term bond return, $r_{SCAP,t}$ is small-cap return all at time *t*. Coefficients $\delta's$ measure the relationship between commercial real estate and other asset returns, and the residual $\varepsilon_{uNPI,t}$ is the pure real estate factor that is not influenced by other return series. Next, we run a regression of equation (2) as

$$r_{LTC,t} = \gamma_0 + \gamma_1 r_{SP500,t} + \gamma_2 r_{uPE,t} + \gamma_3 r_{SCAP,t} + \gamma_4 \hat{\varepsilon}_{uNPI,t} + \varepsilon_{LTC,t} \tag{2}$$

Where residual $\varepsilon_{LTC,t}$ represents the pure bond factor. Coefficients $\gamma's$ measure the relationship between bond, other asset returns and pure real estate factor. Similarly, we run regressions of equations (3) and (4) as

$$r_{uPE,t} = \varphi_0 + \varphi_1 r_{SP500,t} + \varphi_2 r_{SCAP,t} + \varphi_3 \hat{\varepsilon}_{uNPI,t} + \varphi_4 \hat{\varepsilon}_{LTC,t} + \varepsilon_{uPE,t} \tag{3}$$

$$r_{SCAP,t} = \tau_0 + \tau_1 r_{SP500,t} + \tau_2 \hat{\varepsilon}_{uNPI,t} + \tau_3 \hat{\varepsilon}_{LTC,t} + \tau_4 \hat{\varepsilon}_{uPE,t} + \varepsilon_{SCAP,t} \tag{4}$$

where residuals $\varepsilon_{uPE,t}$ and $\varepsilon_{SCAP,t}$ are the respective pure private equity and small-cap stock factors[7]. Coefficients $\varphi's$ measure the relationship between private-equity, stock returns and pure real estate and bond factors, whereas coefficients $\tau's$ measure the relationship between small-cap stock, large-cap returns and other pure factors. In this series of orthogonalized regressions, S&P 500 acts as the numeraire or the base. That is, as independent variables, all pure factors are orthogonalized to S&P 500.

Then, we specify the relationships between REIT returns and the pure factors using a multi-factor asset pricing model as in equations (5) and (6)

$$r_{FREIT,t} = \beta_0 + \beta_1 r_{SP500,t} + \beta_2 \hat{\varepsilon}_{uNPI,t} + \beta_3 \hat{\varepsilon}_{LTC,t} + \beta_4 \hat{\varepsilon}_{uNFI,t} + \beta_5 \hat{\varepsilon}_{SCAP,t} + \mu_t \quad (5)$$

$$r_{TREIT,t} = \omega_0 + \omega_1 r_{SP500,t} + \omega_2 \hat{\varepsilon}_{uNPI,t} + \omega_3 \hat{\varepsilon}_{LTC,t} + \omega_4 \hat{\varepsilon}_{uNTI,t} + \omega_5 \hat{\varepsilon}_{SCAP,t} + \epsilon_t \quad (6)$$

where $r_{FREIT,t}$ and $r_{TREIT,t}$ stand for farmland and timberland REIT returns, respectively. Coefficients β's and ω's measure the influences of different pure factors on REIT returns. Error term or idiosyncratic factor u_t and ϵ_t explain the variations in REIT returns that are unrelated to the independent variables. We estimate equations (5) and (6) by the seemingly unrelated regression (SUR) model to consider the potential cross-equation correlation between the residuals and use the Wald test on the null hypotheses of equal coefficient estimates across farmland and timberland REITs.

Regarding the volatility decomposition, we break down the total return volatility into individual components by using the estimates from the asset pricing models expressed in equations (5) or (6). For example, the variance of farmland REIT return is expressed as

$$Var[r_{FREIT}] \equiv \sigma^2{}_{FREIT} = \beta_1^2 \sigma^2{}_{r_{SP500}} + \beta_2^2 \sigma^2{}_{\varepsilon_{uNPI}} + \beta_3^2 \sigma^2{}_{\varepsilon_{LTC}} + \beta_4^2 \sigma^2{}_{\varepsilon_{uNFI}} + \beta_5^2 \sigma^2{}_{\varepsilon_{SCAP}} + \sigma_\mu^2 \ . \quad (7)$$

Using equation (7), we calculate the relative contributions of each factor to the total farmland REIT

[7] $r_{uPE,t} = r_{uNFI,t}$ and $\varepsilon_{uPE,t} = \varepsilon_{uNFI,t}$ for farmland REIT regression whereas $r_{uPE,t} = r_{uNTI,t}$ and $\varepsilon_{uPE,t} = \varepsilon_{uNTI,t}$ for timberland REIT regression.

Return volatility as,

$$\text{Large-cap stock} = \frac{\beta_1^2 \sigma^2{}_{r_{SP500}}}{\sigma^2{}_{FREIT}}$$

$$\text{Real estate} = \frac{\beta_2^2 \sigma^2{}_{\varepsilon_{uNPI}}}{\sigma^2{}_{FREIT}}$$

$$\text{Bond} = \frac{\beta_3^2 \sigma^2{}_{\varepsilon_{LTC}}}{\sigma^2{}_{FREIT}}$$

$$\text{Private-equity farmland} = \frac{\beta_4^2 \sigma^2{}_{\varepsilon_{uNFI}}}{\sigma^2{}_{FREIT}}$$

$$\text{Small-cap stock} = \frac{\beta_5^2 \sigma^2{}_{\varepsilon_{SCAP}}}{\sigma^2{}_{FREIT}}$$

$$\text{Idiosyncratic} = \frac{\sigma_u^2}{\sigma^2{}_{FREIT}}\,. \qquad (8)$$

State-space model with Kalman filtering

The regression estimation assumes a constant relationship between REIT returns and other factors and does not capture the changing pattern of REIT return volatility. Thus, we employ a state-space framework with the Kalman filter to examine the time-dependent relationships. The state-space model has been widely applied in empirical financial research in analyzing dynamic systems that are measured through some stochastic processes. The Kalman filter is one of the optimal estimation tools that recursively estimates the state vector at time *t*. Using equations (5) and (6), we specify the system of equations in the state-space framework for the REITs. For example, the farmland REIT model is specified as

$$r_{FREIT,t} = \beta_0 + \beta_{1t} r_{SP500,t} + \beta_{2t}\hat{\varepsilon}_{uNPI,t} + \beta_{3t}\hat{\varepsilon}_{LTC,t} + \beta_{4t}\hat{\varepsilon}_{uNFI,t} + \beta_{5t}\hat{\varepsilon}_{SCAP,t} + \mu_t \qquad (9)$$

$$\beta_t = \beta_{t-1} + \eta_t \qquad (10)$$

where β_t is a 5×1 vector of the slope coefficients that follows a random walk process, and η_t is the error term at time *t*. Equation (9) is the observation or measurement equation that explains the relation between the observed variables and the unobserved state variables. Equation (10) is the state equation that shows the dynamics of the unobservable state variables[8]. The *KFAS* package (version 1.4.6) in the R programming language is used to estimate the state-space model with the Kalman filter (Helske, 2021).

Empirical Results

Descriptive statistics of return indices

Figure (4.1) shows the quarterly time series of return indices from 2013 to 2021. All private equities, uNTI, uNFI, and uNPI, exhibit stable trends over time. In contrast, public equities are much more volatile, with SCAP and TREIT exhibiting greater volatility than S&P 500 and FREIT. In addition, FREIT closely tracks SCAP whereas TREIT closely tracks S&P 500, especially in the mid and the later phases of the sample. Some analogous patterns can be observed across public equities. For example, S&P 500, SCAP and TREIT suffered from substantial losses triggered by the outbreak of COVID-19. In fact, they realized the maximum loss in the whole sample period but rebounded quickly to their maximum and remained mostly positive thereafter. FREIT, on the other hand, did not fall as sharply as the other return indices. Potential reasons behind this are the countercyclical nature of farmland investments, and the stable and continuous demand for food (Green Street, 2021). While uNTI tends to lag the public-equity timberland market (Mei and Clutter, 2020), no distinct pattern is observed in the shorter time frame.

Summary statistics of all the indices are reported in Table 4.2. The quarterly means of all return indices are positive. Overall, stocks have greater mean returns with moderate to high volatilities than other assets. Small-cap stocks have the highest mean return of 4.3% and the highest

[8] Details on state space model and Kalman filtering in Harvey (1989).

Volatility of 14.4%, whereas large-cap stocks have a high mean return of 3.7% and a much lower volatility of 7.0%. On the other hand, bonds have the lowest mean return of 0.9% and the lowest volatility of 0.2%. Farmland and timberland REITs have a similar mean return of 2.9% with a relatively higher risk of roughly 13%. In contrast, private-equity farmland and timberland exhibit lower mean returns of 1.9% and 1.2% as well as lower volatilities of 4.9% and 3.8%, respectively. Lastly, private-equity real estate shows a moderate mean return of 2.4% and a much lower risk of 1.9%. In regard to correlations, FREIT is positively correlated with all other return indices except for uNFI and LTC. Specifically, FREIT exhibits a strong correlation of 0.590 with S&P 500, 0.583 with SCAP, and -0.474 with LTC. Similarly, TREIT is positively correlated with all other return indices except for LTC. TREIT exhibits a strong correlation of 0.882 with S&P 500 and 0.734 with SCAP, and a moderate correlation of -0.326 with LTC. Other return indices also show strong correlations with each other. For example, SCAP is strongly positively correlated with S&P 500 and fairly negatively correlated with LTC, with a correlation coefficient of 0.814 and -0.261, respectively.

Summary statistics of pure factors used in the final multi-factor models, i.e., equations (5) and (6), are presented in Tables A1 and A2 in the Appendix. After the orthogonalization, the pure factors of all indices are uncorrelated with each other. FREIT exhibits a lower correlation with the uNFI, uNPI and SCAP factors and a somewhat higher correlation with the LTC factor, whereas TREIT shows a lower correlation with all the pure factors. Overall, the orthogonalization step addresses the cross influence and allows us to estimate the marginal effect of an individual asset on REIT returns and volatility decomposition.

SUR model and volatility decomposition results

Table (4.3) reports the return sensitivity of farmland and timberland REITs to the pure factors using the SUR model. The contemporaneous coefficients on bond and private equity factors are negative, whereas those on the rest factors are positive for both farmland and timberland REITs. The large-cap stock factor exhibits a greater influence on timberland than farmland REIT returns, whereas the small-cap stock factor exhibits a greater effect on farmland. This could be owed to the fact that farmland REITs are relatively small in size. Both REIT returns are significantly sensitive to the large-cap stock factor at the 1% level. Bond is another financial factor that exerts a significant effect on farmland REIT returns at the 5% level. The real estate and private-equity factors do not play significant roles in explaining the variation in REIT returns. The Wald test results confirm that the large-cap stock factor has a significant higher influence on timberland than farmland REIT returns at the 10% level. Coefficients on other factors are not statistically different at the 10% level. For the volatility decomposition in Table (4.4), we rely on the estimates from the SUR model to quantify each pure factor's contribution to the REIT return volatility. Overall, results suggest that the REIT returns are influenced by two common factors, large-cap stocks and bonds, for the chosen sample period.

While the return volatility of farmland REITs is somewhat decomposed among all the factors, that of timberland REITs is concentrated on the large-cap stock and idiosyncratic factors. Specifically, factors other than the large-cap stock and idiosyncratic factors together contribute about 17% to farmland REIT volatility but only 2.3%to timberland REIT volatility. The real estate, bond and small-cap stock factors explain more variations in farmland than timberland REIT returns. The idiosyncratic factor contributes most (51.72%) to farmland REIT volatility, followed by the large-cap stock factor (31.58%). In contrast, the large-cap stock factor contributes most (75.22%) to timberland REIT volatility, followed by the idiosyncratic factor (22.48%). Private-equity farmland and timberland factors, nonetheless, play trivial roles in explaining the corresponding REIT volatilities. Based on the static model, farmland REIT return is more sensitive to industry specific information, while timberland REIT return is more sensitive to large-cap stocks.

State-space estimation results

We employ a state-space model with the Kalman filter and use its coefficient estimates combined with the volatilities of the pure factors to generate the time-dependent volatility decompositions of REIT returns. Figures (4.2) and (4.3) demonstrate the pattern of the volatility contribution from the pure factors to farmland and timberland REITs over time. All except for the real estate and idiosyncratic factors have a substantial impact on farmland REIT volatility. Unlike the results from the static model, the large-cap stock factor contributes more to farmland REIT volatility most of the times throughout the sample, whereas the importance of the idiosyncratic factor falls. In the earlier years of farmland REIT formation and growth, bond effect is high, but its relevance diminishes subsequently. The small-cap stock and private-equity farmland factors exhibit similar trends in explaining the variation in farmland REIT return. While there is little material impact of both factors in the earlier years, their contributions rise after 2015. It is also important to note that small-cap stocks consistently contribute more than private-equity farmland until the late 2018, but the trend reverses afterwards. Towards the end of the sample period, the large-cap stock effect increases dramatically whereas that of all other factors fall.

For timberland REITs, results reveal a substantial effect of large-cap stocks on the volatility. Consistent with the results from the static model, the large-cap stock effect is substantially and consistently high in the whole sample period. However, the contribution varies over time, ranging from 53% to 89%. While there is little material impact of private-equity timberland in the earlier years, it rises slightly after 2015. Conversely, the contribution of small-cap stock factor diminishes after 2015 but increases to 36% in the late 2018. The real estate and bond factors contribute negligible fractions to timberland REIT volatility.

For both farmland and timberland REITs, the contribution of the large-cap stock factor decreases between 2016 and 2019, whereas that of the small-cap stock factor increases. Although the real estate and idiosyncratic factors do not play important roles in explaining REIT return volatility, the bond factor exhibits a greater impact on farmland REITs despite a declining trend. The importance of the private equity counterparty rises after 2015 for both types of REITs, but the effect on farmland REIT volatility is comparatively higher over time. Overall, the volatility decomposition results reveal a greater effect of the large-cap stock factor on timberland REITs while a greater effect of the small-cap stock factor on farmland REITs. Hence, such time-dependent relationships between REIT returns and other asset factors suggest some structural shifts in the return characteristics of farmland and timberland REITs.

Discussion and Conclusions

In the recent years, the demand for farmland has been increasing worldwide due to a steady demand for food coupled with a shrinking supply of arable land as a result of a growing population (Green Steet, 2021). In fact, the influx of capital from institutional investors has increased farmland value to $3000/acre as of 2015 (Mei *et al.*, 2020). Similarly, timberland market is emerging and receiving a growing recognition due to its contributions to environmental, social, and economic development. While these assets may suffer from volatile commodity prices, a steady growth in crop or timber yield and land value can balance it out. As such, asset allocation strategies of institutional investors may consider farmland and timberland REITs in a multi-asset portfolio to gain some exposure to these alternative investments. However, little is known whether these entities provide additional exposure to the capital market over time. Thus, we evaluate the time-dependent relationships of public farmland and timberland REITs with some selected asset classes.

We first orthogonalize return indices to obtain pure factors to price farmland and timberland REITs under a SUR framework, and then generate the time-dependent volatility decompositions under the state-space framework. Results from the SUR model suggest that farmland REITs are more sensitive to the bond factor, whereas timberland REITs are more sensitive to the large-cap stock factor. This implies that farmland and timberland REITs are highly integrated with the financial market in terms of common macroeconomic factors affecting their returns. Surprisingly, farmland REIT returns do not have a significant loading on the small-cap stock factor in our multi-factor asset pricing model despite their relatively small size. Similarly, the return sensitivity of farmland and timberland REITs to the real estate factor is not significant, suggesting that their returns are influenced by different market fundamentals. In the private equity market, similar integration between the timberland-farmland and real estate assets is observed by Mei *et al*. (2020). Despite the apparent association of farmland and timberland REITs with their private equity counterparties, there is no significant effect of respective private equity factors on REIT returns. Therefore, we conclude that farmland and timberland REITs share some common return drivers with the financial assets on a quarter-by-quarter basis.

The correlation coefficients and the asset pricing model results suggest a strong relationship between farmland and timberland REITs and some other asset classes. However, they do not necessarily imply a limited diversification potential of both REITs (Lee and Stevenson, 2007). To provide further evidence on their diversification abilities, we examine the volatility contributions of each pure factor and find that the large-cap stock and idiosyncratic factors have more pronounced effects on farmland and timberland REITs. The idiosyncratic factor explains more than half of the farmland REIT volatility. In contrast, the large-cap stock factor alone captures almost three-fourth of the timberland REIT volatility. Consistent with Lee and Stevenson (2007) and Anderson *et al.* (2005), we find that there is a unique element to farmland REITs, suggesting that they can provide some diversification benefits beyond those of financial and private equity assets. Additionally, the bond factor has a negligible contribution to the volatility despite its significant role in pricing farmland and timberland REITs.

From the time-dependent volatility analysis, we find substantial variations in the contributions of several asset factors, suggesting that the farmland and timberland REIT characteristics indeed change over time. For example, the bond factor contributes more to the farmland REIT volatility during the earlier years when the REITs were formed or mergers took place. The large-cap stock factor plays a dominant role in contributing to farmland and timberland REIT volatility throughout the sample period. However, during the periods of unstable commodity prices between 2013 and 2015 and the COVID-19 (Key *et al.*, 2019), the effect of the large-cap stock factor to farmland volatility declines transitorily whereas that of the idiosyncratic component spikes. This echoes the sensitivity of farmland REIT return to firm-specific information in certain periods as observed in the REIT sector in general (Clayton and Mackinnon, 2003). In addition, the increase in interest rate between 2016 and 2019 had a ripple effect on the contributions of the large-cap stock factor to REIT return volatility. During this period, the importance of the large-cap stock factor declines, thereby exhibiting a lower contribution to farmland than timberland REIT volatility. Conversely, the contributions of the small-cap stock and private equity factors to farmland REIT volatility increase during the high interest rate period.

While farmland REITs retain some investment characteristics of several asset classes, timberland REITs increase the overall exposure to the large-cap stocks, which is consistent with the findings of Piao *et al.* (2016) and Mei (2017). We conclude that timberland REITs offer limited diversification benefits than farmland REITs in a portfolio that consists of large-cap stocks. As the effect of the overall stock market on farmland and timberland REIT volatility increases over time, we argue that both sectors are still in the developing phase. Timberland and farmland REITs are considering the environmental, social and governance factors into investment activities and strategizing their operations to capture the maximum growth. Looking forward, these entities can provide variety of investment opportunities to a broad group of investors. Given that the asset allocation decision would also depend on some other factors including risk levels, investment holding period, needs, and interests of investors, future studies can consider some of these factors and explore their explanatory power on farmland and timberland REIT returns.

Acknowledgements

United States Department of Agriculture Grant GEOZ-0199-MS partially funded this research.

Table 4.1. Public farmland and timberland real estate investment trusts (REITs) in the US.

Farmland REITs	Inception year	Acreage (Mil. Acres)	Market cap (billion $)	Timberland REITs	Inception year	Acreage (Mil. Acres)	Market cap (billion $)
Gladstone Land Corporation	2013	0.1	1.2	Rayonier	2004	2.7	5.7
Farmland Partners	2014	0.2	0.5	PotlatchDeltic	2006	1.8	4.1
				Weyerhaeuser	2010	11.0	30.8
				CatchMark	2013	0.4	0.4

Notes: Data come from company websites. Rayonier owns or leases 0.4 million acres in New Zealand and Weyerhaeuser leases 13.9 million acres in Canada.
Market capitalization is stock price times shares outstanding as of December 31, 2021 (WRDS 2021).

Table 4.2. Summary statistics and correlations of selected return indices (2013Q1-2021Q4).

	FREIT	TREIT	uNFI	uNTI	uNPI	S&P 500	SCAP	LTC
Mean	0.029	0.029	0.019	0.012	0.024	0.037	0.043	0.009
SD	0.127	0.129	0.049	0.038	0.019	0.070	0.144	0.002
Minimum	-0.177	-0.378	-0.079	-0.051	-0.036	-0.200	-0.338	0.006
Maximum	0.309	0.279	0.187	0.132	0.077	0.199	0.423	0.011
Correlations								
FREIT	1.000							
TREIT	0.518	1.000						
uNFI	-0.002	0.119	1.000					
uNTI	0.102	0.071	0.869	1.000				
uNPI	0.139	0.072	0.133	0.248	1.000			
S&P500	0.590	0.882	0.213	0.171	0.053	1.000		
SCAP	0.583	0.734	0.038	-0.025	-0.190	0.814	1.000	
LTC	-0.474	-0.326	0.091	0.014	-0.100	-0.231	-0.261	1.000

Notes: FREIT, a portfolio of public farmland real estate investment trusts (REITs); TREIT, a portfolio of public timberland REITs; uNFI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Farmland Index; uNTI, unsmoothed NCREIF Timberland Index; uNPI, unsmoothed NCREIF Property Index; S&P 500, a portfolio of large-cap stocks; SCAP, a portfolio of small-cap stocks; and LTC, AAA Long-term corporate bond Index.

Table 4.3. Return sensitivity of farmland and timberland REITs to pure factors.

Factors	Farmland REIT		Timberland REIT	
	Estimates	*p*-value	Estimates	*p*-value
Constant	-0.009	0.62	-0.029	0.02
Large-cap stock	1.067	0.00	1.613	0.00
Real estate	1.061	0.25	0.221	0.71
Bond	-26.775	0.02	-10.237	0.15
Private equity	-0.243	0.49	-0.241	0.41
Small-cap stock	0.269	0.18	0.042	0.74

Wald test		
H_0	χ^2	*p*-value
$\beta_1 = \omega_1$	3.47	0.06
$\beta_2 = \omega_2$	0.53	0.47
$\beta_3 = \omega_3$	1.49	0.22
$\beta_4 = \omega_4$	0.00	0.99
$\beta_5 = \omega_5$	0.85	0.36

Notes: REIT for real estate investment trust. Private equity represents unsmoothed private-equity farmland or timberland factors.

Pure factors in equations (5) and (6) come from the orthogonalized regression.

β's and ω's are the coefficient estimates from equations (5) and (6).

Table 4.4. Contributions (in percentage) of pure factors to farmland and timberland REIT return volatility.

Factors	Farmland	Timberland
Large-cap stock	31.58	75.22
Real estate	2.26	0.10
Bond	10.43	1.61
Private equity	0.81	0.50
Small-cap stock	3.20	0.08
Idiosyncratic	51.72	22.48

Notes: REIT for real estate investment trust. Private equity represents unsmoothed private-equity farmland or timberland factors.
Pure factors in equations (5) and (6) come from the orthogonalized regression.

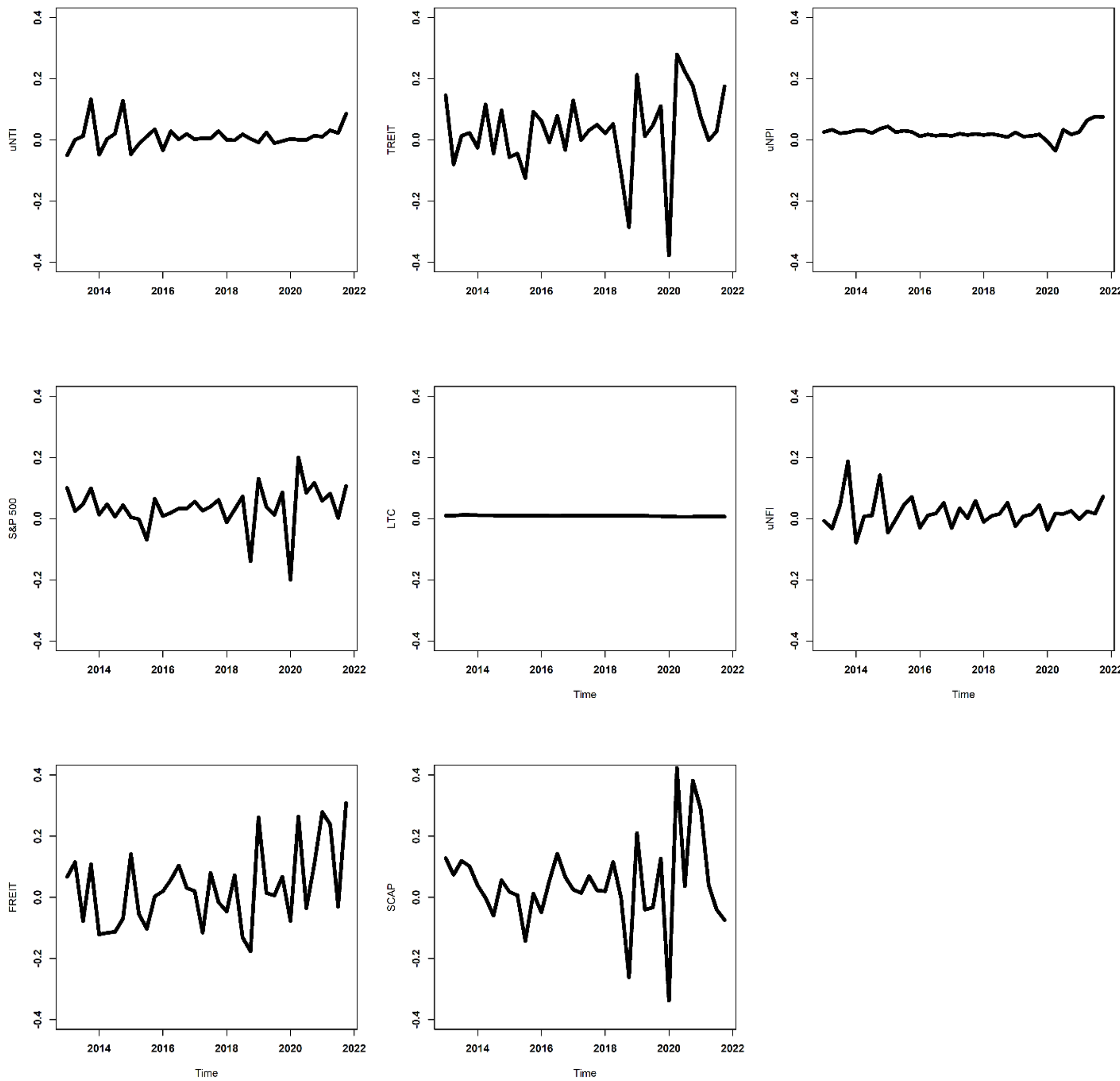

Figure 4.1. Trend of selected raw return indices (2013Q1-2021Q4).
Notes: FREIT, a portfolio of public farmland real estate investment trusts (REITs); TREIT, a portfolio of public timberland REITs; uNFI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Farmland Index; uNTI, unsmoothed NCREIF Timberland Index; uNPI, unsmoothed NCREIF Property Index; S&P 500, a portfolio of large-cap stocks; SCAP, a portfolio of small-cap stocks; and LTC, AAA Long-term corporate bond Index.

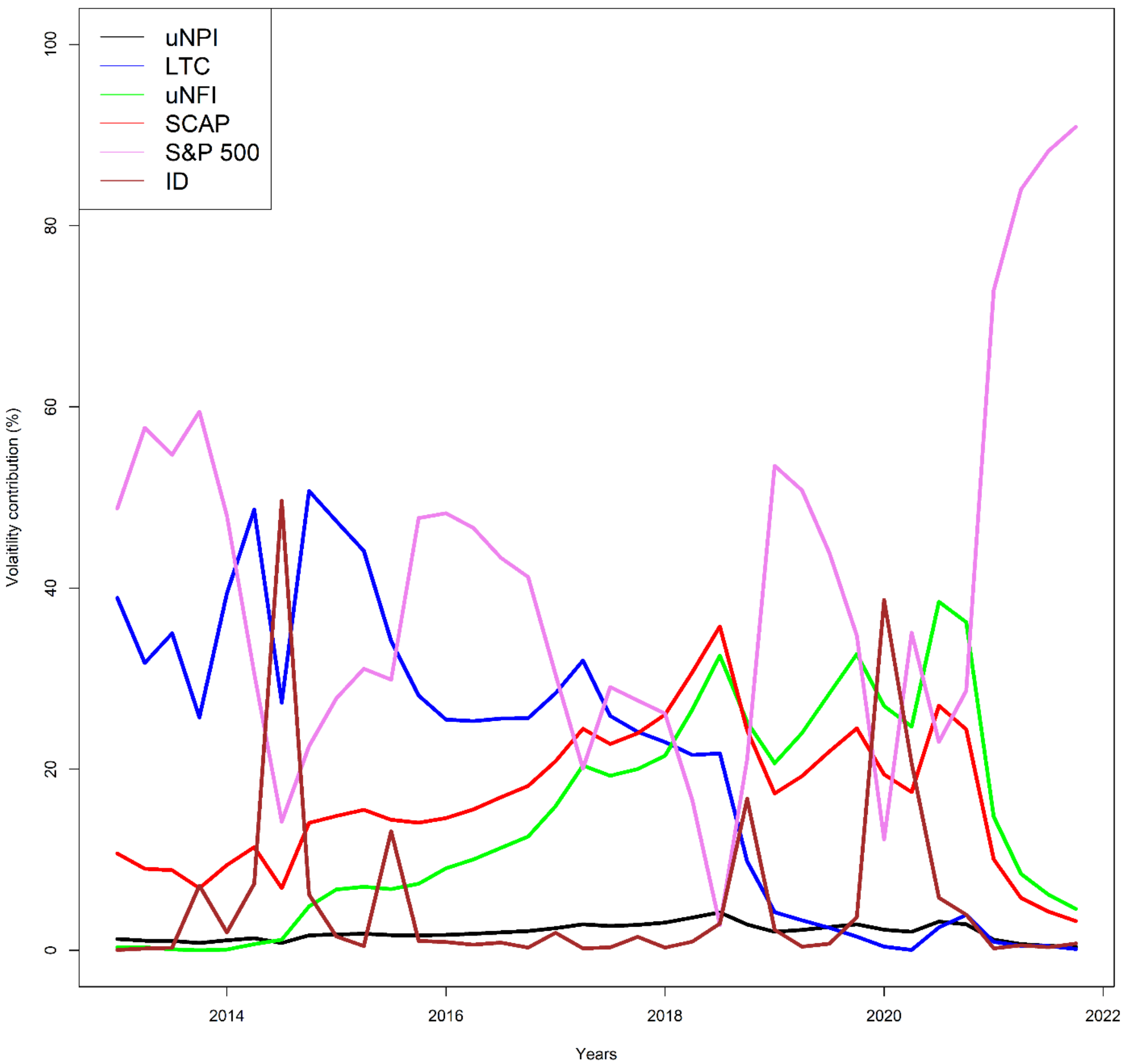

Figure 4.2. Time-dependent volatility contributions of orthogonalized S&P 500, small-cap stocks, long-term corporate bonds, private real estate, private farmland and idiosyncratic (ID) factors to farmland REIT return.

Notes: REIT, real estate investment trust; uNFI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Farmland Index; uNPI, unsmoothed NCREIF Property Index; S&P 500, a portfolio of large-cap stocks; SCAP, a portfolio of small-cap stocks; and LTC, AAA Long-term corporate bond factors.

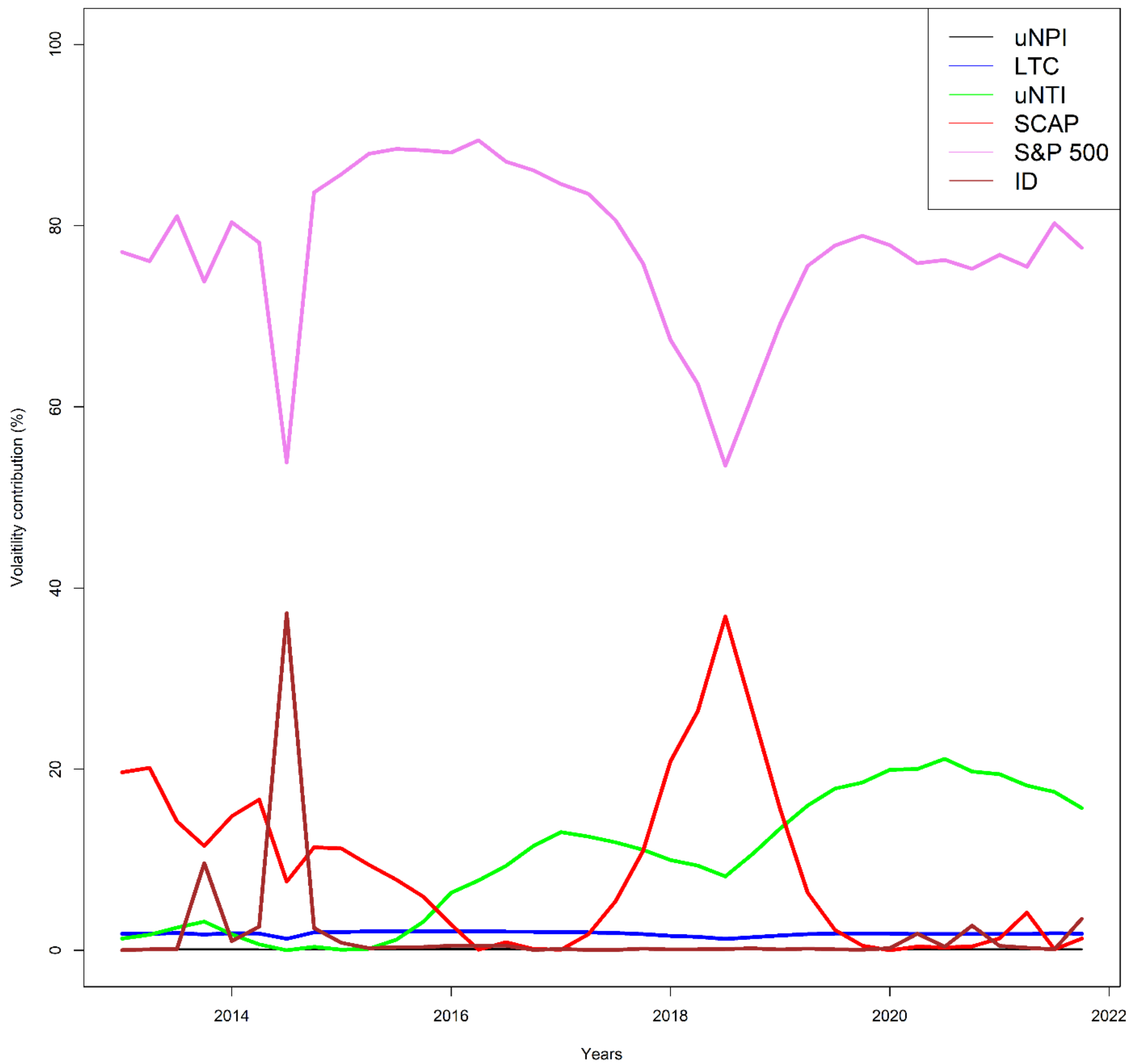

Figure 4.3. Time-dependent volatility contributions of orthogonalized S&P 500, small-cap stocks, long-term corporate bonds, private real estate, private timberland and idiosyncratic (ID) factors to timberland REIT return.

Notes: REIT, real estate investment trust; uNTI, unsmoothed National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index; uNPI, unsmoothed NCREIF Property Index; S&P 500, a portfolio of large-cap stocks; SCAP, a portfolio of small-cap stocks; and LTC, AAA Long-term corporate bond factors.

Appendix

Table A1. Descriptive statistics of pure factors in equation (5).

	Private-equity farmland	Real estate	Small-cap stocks	Bond
Mean	0.000	0.000	0.000	0.000
SD	0.047	0.018	0.084	0.002
Minimum	-0.089	-0.054	-0.233	-0.003
Maximum	0.153	0.046	0.209	0.002
Correlations of FREIT with all the pure factors				
Private-equity farmland	-0.091			
Real estate	0.149			
Small-cap stocks	0.177			
Bond	-0.319			

Notes: FREIT, a portfolio of public farmland real estate investment trusts; SD, standard deviation. Large-cap stock is the base in equation (5).

Table A2. Descriptive statistics of pure factors in equation (6).

	Private-equity timberland	Real estate	Small-cap stocks	Bond
Mean	0.000	0.000	0.000	0.000
SD	0.036	0.018	0.084	0.002
Minimum	-0.071	-0.054	-0.233	-0.003
Maximum	0.116	0.045	0.209	0.003
Correlations of TREIT with all the pure factors				
Private-equity timberland	-0.076			
Real estate	0.032			
Small-cap stocks	0.027			
Bond	-0.121			

Notes: TREIT, a portfolio of public timberland real estate investment trusts; SD, standard deviation. Large-cap stock is the base in equation (6).

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CHAPTER 5

CONCLUSIONS

In recent years, timberland and farmland investments have become increasingly attractive alternative asset classes. Timberland and farmland REITs, in particular, are accepted by the broad market as mechanisms to invest in real estate assets that are tax efficient. However, many aspects of these REITs have not been explored yet. This dissertation examines three issues related to timberland and farmland REITs: (i) a literature review on the development and financial performance of timberland REITs in the United States, (ii) the time-varying relationships of timberland REITs with the financial and private equity assets, and (iii) the risk and return characteristics of farmland REITs versus timberland REITs.

Chapter 2 takes a comprehensive look at the current scientific literature on how the timberland REITs have evolved and performed in the United States. Using 42 peer reviewed articles on timberland REIT analysis, we find a growing interest of individual and institutional investors in timberland REIT investment due to high liquidity, tax efficiency, and small capital to be invested. In the last two decades, several forest products companies converted themselves to a REIT and expanded the location and size of timberland properties post conversions. This attracted many research interests on the impacts of REIT conversions and the risk return characteristics of timberland REITs. While the REIT structure of timberland investment has received positive market reaction, timberland REITs tend to introduce non-diversifiable systematic risk. Methodologies used in the financial analysis of timberland REITs are also examined. In contrast to single-factor asset pricing models (e.g., capital asset pricing model), multi-factor models can better capture the financial characteristics of timberland REITs.

Chapter 3 uses a multi-factor asset pricing model and a state space framework with the Kalman filter to examine the time-varying characteristics of timberland REIT returns. All the independent variables including private-equity timberland, real estate, large-cap stock, and long-term corporate bond are orthogonalized to obtain pure factors and to decompose REIT volatility into these asset components. Multi-factor model results show a greater return sensitivity of timberland REIT to the financial asset factors, suggesting that their returns are influenced by some common state variables. State space results reveal higher contributions of the large-cap stock and industry-level risk factors to timberland REIT volatility. Timberland REIT offers limited diversification benefits in portfolios that consist of large-cap stocks and their characteristics also change over time. Future research can use higher frequency data and compare the financial features of timberland REITs with other types of REITs.

Chapter 4 compares the integration of farmland and timberland REITs with their private equity counterparties and other selected asset classes. The selected asset classes include commercial real estate, large-cap stock, small-cap stock, and long-term corporate bond. We use the quarterly return data from 2013 to 2021 to match the farmland REIT data. Multi-factor asset pricing models are estimated for farmland and timberland REITs via seemingly unrelated regression and the volatility decompositions are estimated under a state space framework with the Kalman filter. Results show that the financial asset factors play significant roles in pricing farmland and timberland REITs and that the large-cap stock factor contributes more to REIT volatility despite some differing patterns between farmland and timberland REITs. The bond, small-cap stock, and private-equity factors exhibit a larger effect on farmland than timberland

REIT volatility. Because the effect of the large-cap stock factor increases whereas that of the idiosyncratic factor decreases over time, we conclude that the farmland and timberland sectors are still in the developing phase. Overall, these results improve our understanding of portfolio optimization.

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